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# XDELIA

## EMOTION-CENTRED FINANCIAL DECISION-MAKING AND LEARNING



Competence in financial matters has become part and parcel of everyday life, both at the work place and in our daily lives. Traditional learning cannot deliver the necessary skills, and more innovative solutions are needed. Serious games, wearable sensors, and a focus on emotions lie at the heart of this project's novel, technology-supported approach to expertise and competence-building in financial decision making.

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# XDELIA

## EMOTION-CENTRED FINANCIAL DECISION-MAKING AND LEARNING

xDelia is a 3-year pan-European project building on the knowledge, skills, and competences of seven partner organisations from a variety of research disciplines and from business. The principal objective of xDelia is to develop technology-enhanced learning approaches that help improve the financial decision making of investors who trade frequently using an electronic trading platform. We focus on emotions, and how they affect maladaptive decision biases and trading performance. Our earlier field work with traders has shown that the development of emotion regulation skills is a key facet of trader expertise. For that reason we consider expert traders our benchmark for adaptive behaviour rather than normative rationality. Our goal is to provide investors with the tools and techniques to develop greater self-awareness of internal states, increase their ability to reflect critically on emotion-informed choices, develop emotion management skills, and support the transfer of these skills to the real-world practice setting of financial trading.

This report provides a comprehensive overview of what xDelia is about and what we have achieved over the life of the project. In the sections that follow, we explain the decision problems investors are faced with in a fast paced environment and the limitations of traditional approaches to reduce cognitive errors; introduce an alternative, technology-enhanced learning approach of diagnosis and feedback, skill development, and transfer; describe the learning intervention comprising twelve autonomous learning elements that we have developed; and present evidence from thirty-five studies we have conducted on learning effects and stakeholder acceptance.

Much of this document is based on the thirty or so project deliverables, which offer far more detailed and definite discussion on the various aspects that we could only sketch out here. We have provided references to these deliverables throughout the document.

## PARTNERS

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Högskola

CIMNE

Erasmus University

Forschungszentrum

Informatik

The Open University

Saxo Bank

University of Bristol

[www.xdelia.org](http://www.xdelia.org)

The remainder of this report is divided into five sections:

**The xDelia project** – summarises what xDelia tries to achieve, the learning intervention we have developed and the instruments we have used in the process, how the work unfolded over the three years, and how we evaluated our work and the project output.

**The concept and purpose of the learning intervention** – describes the challenge of reducing and overcoming financial decision biases, and the alternative approach we have developed, the investor target group, and the pedagogy underpinning our learning intervention.

**The xDelia learning pathway** – describes the pedagogical framework and the three stage learning approach of diagnosis and feedback, skill development, and learning transfer.

**Elements of the learning pathway** – briefly describes the purpose and key features of each of the learning elements within the learning intervention.

**Evidence-based design and evaluation** – presents an overview of the evaluation of the learning elements and of the user experience.

For further details about xDelia, project publications and deliverables, and contacts, please visit the project web site at [www.xdelia.org](http://www.xdelia.org).

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## XDELIA – A BIRD'S EYE VIEW

### What is xDelia?

#### BACKGROUND AND PURPOSE

The core purpose of xDelia is to develop learning approaches to improve the financial decision making of investors who trade frequently using a trading platform. A central proposition of the xDelia project is that maladaptive behaviours in financial decision-making can be reduced through more effective regulation of emotions whilst still allowing the application of emotion-mediated expert intuition. Investigating this, the project has developed new, technologically supported approaches to training; and support for non-formal and informal learning in real-world settings to tackle the challenges faced by investors when they make financial decisions.

xDelia is a 3-year pan-European project building on the knowledge and skills of seven partners from different institutions, with different areas of expertise. The expertise in trader and investor behaviour is shared between the Business School at the Open University and the Research Department at Saxo Bank in Copenhagen. The University of Bristol, in collaboration with CIMNE, provides the expertise in individual financial capability. Two universities, FZI in Germany and Erasmus University in the Netherlands deal with triggering and measuring emotional responses using a variety of bio sensors. The serious games expertise is located in BTH in Sweden and the project management is based in CIMNE in Barcelona with project evaluation activities coordinated from the OU in the UK.

We have collaborated to produce a learning intervention, called the xDelia Learning Pathway, that incorporates a range of technologies, including wearable bio-sensors and serious games. The primary focus of the project is on the production of learning approaches for individuals who typically already have significant knowledge about the investment domain, are highly motivated to learn techniques which can improve their performance, and often engage proactively with a wide range of learning resources. This group has significant and growing economic importance in the EU, and is sufficiently well understood to be a viable target of learning interventions.

In order to design an effective learning intervention, we have worked together to identify and address the effects of emotional regulation on the financial decision making of traders and investors. To that end, xDelia has produced and evaluated learning approaches which employ physiological sensors, serious games, and mindfulness training with a strong focus on building awareness of emotions and on developing emotion regulation skills. Because of the well-known problems of learning transfer and the need to support the development of expertise over extended period, the design of the learning intervention does not rely solely on learning games, but also includes approaches to support transfer of learning into the 'real-world' practice setting.

The interdisciplinary nature of the project and the geographical distribution of the partners presented xDelia with some unique challenges. Part of our evaluative approach, which we describe in section 6 below, involved identifying these challenges, and tracking and evaluating how they have been addressed during the project.



## FOCUSING ON EMOTIONS

Much financial training has, to date, focused primarily on imparting propositional knowledge and increasing people's understanding. However, investors may have appropriate knowledge, but despite this go on to be ruled by their attitudes, habits, or emotional states. Emotions mediate both rapid expert situation recognition and the application of expert intuition but also important persistent biases in decision-making such as framing effects and the disposition effect in particular. It is common in the judgment and decision-making literature (e.g. Bazerman, 2002; Kahneman & Tversky, 1979) to treat emotions as either simply a component of future utility (e.g. anticipated regret) or a disturbance to optimal decision-making. In contrast our position is that emotions are inextricably intertwined with cognition at all stages of decision-making<sup>1</sup> and play an important adaptive role in fast and frugal decision-making. Moreover, while we do have a focus on reducing maladaptive biases in financial decision-making our benchmark for adaptive behaviour is not, as in the judgement and decision-making literature, a normative model of optimally (or boundedly) rational behaviour. Rather we take as our benchmark the behaviour of expert traders.

Recognising the problems with traditional de-biasing approaches, our goal has been to develop learning approaches (i) which do not simply depend on increasing self-monitoring behaviours, (ii) which integrate well with practitioners' informal learning, and (iii) support the process of developing expertise. Our earlier field work with traders has shown that the development of emotion regulation skills is a key facet of trader expertise (Fenton-O'Creevy et al., 2012; Fenton-O'Creevy et al., 2011). The important question therefore for traders and investors who trade frequently is not whether they have emotions, but how they engage with them. Hence, an effective learning design should not seek to eliminate the role of emotions in financial decision-making, nor should it replace heuristic decision-making with slower and cognitively more effortful normatively rational analysis. Rather, the focus should be on developing greater self-awareness of internal states (interoception) and increased ability to reflect critically on emotion-informed choices rather than on the elimination of emotions. This is what we have done in the xDelia project.

## The learning intervention

### DEVELOPING THE XDELIA LEARNING PATHWAY

A key milestone of the xDelia project was the design and implementation of a learning intervention, the xDelia Learning Pathway, that incorporated serious games and bio-feedback, to help private investors acquire better emotion regulation skills, and support the transfer of these skills to their real-world trading context. The ultimate goal was to improve their financial decision making and trading performance under pressure through better management of emotions. Furthermore, the learning pathway had to provide support for informal, self-directed learning that is both engaging and relevant to the learning needs of private investors. Workshops and studies guided the design of the learning pathway and its elements throughout the life of the project.

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<sup>1</sup> See Phelps (2006) for a recent major review on this topic

The xDelia Learning Pathway builds on an integrated approach that frames learning objectives at three levels:

**Level 1: Diagnosis and Feedback**

Understanding the DE and emotion regulation strategies and how they relate to investor trading, and improved awareness of personal profile in relation to the DE and habitual emotion regulation strategies.

**Level 2: Skill Development**

Development of skills in recognising and avoiding the DE and in effective emotion regulation in a learning environment.

**Level 3: Transfer**

The transfer of skills from the learning environment into the real-world trading context.

To achieve these objectives, the xDelia Learning Pathway helps learners build an understanding of their own decision patterns and styles, offers timely and relevant feedback, provides a learning environment for skill acquisition and practice, and supports the transfer of skills into learners' real-world practice of trading.

The xDelia Learning Pathway is founded on informal learning principles and consists of a flexible set of learning elements designed to work together and teach investors strategies to manage their emotions and improve their decision making under stress. Each learning element, whether it is an online game, a questionnaire, a mobile app, the diary tool or the peer forum, is standalone, so that learners can mix and use these elements to best suit their learning needs.

In an idealised form, the xDelia Learning Pathway runs through three stages and lasts typically between 6 weeks and 6 months. A first stage incorporates elements that diagnose a learner's habitual emotion regulation strategies and trading bias, and that feed this information back to raise awareness. A second stage offers learning elements that develop emotion regulation skills and address the learning needs identified in Stage 1. And a the third stage supports the consolidation and transfer of these emotion regulation skills to real world practice through reflection and through engagement with a network of peers. While the idea of 'stages' suggests a linear pathway, it is likely that in practice this plays out in a much more iterative fashion, with participants returning to earlier diagnostic and skill development phases as they work on transferring these skills into their daily trading practice.

**THE LEARNING ELEMENTS**

The xDelia Learning Pathway consists of a modular set of learning elements, ranging from diagnostic tools to identify the personalised learning needs of each learner, through training activities to teach emotion regulation techniques, to serious games activities to practice and improve these techniques. Learning elements may be combined in different ways and run in various modes depending on where the learner finds herself in the learning pathway. Each learning element addresses one or more learning objectives and can be undertaken alone or in combination with other learning elements.

A total of 12 learning elements have been developed and evaluated in the xDelia Project:

**Diagnostic questionnaire** – to diagnose habitual emotion regulation strategies

**Behind-the-scenes algorithms** – to calculate the disposition effect (DE) based on real trading data

**Feedback on emotion regulation score** – to teach awareness of personal emotion regulation strategies

**Feedback on DE score** – to teach awareness of personal tendency to DE

**Two Index game in diagnostic mode (TIG-DIAG)** – to teach awareness of personal tendency to exhibit the DE

**Mobile Mindfulness app** – to practice mindfulness techniques for emotion regulation

**Mindfulness game** – to practice mindfulness techniques for emotion regulation

**Auction game** (biosensors) in didactic mode (AUC-DIDAC) – to practice emotion regulation under stress

**Space Investors game** (biosensors) in didactic mode (SI-DIDAC) – to practice emotion regulation under stress

**Two Index game** in didactic mode (TIG-DIDAC) – to practice emotion regulation during a financially realistic task with real-time visual display of DE

**Peer forum** – to provide interaction with other learners and more able peers, sharing experiences, reflections, ideas and skill transfer

**Online diary** – to record trading and emotional state together with state-of-the-market data for reflection and to support skill transfer

## Implementing xDelia

### THE INSTRUMENTS

The bulk of the work undertaken in xDelia consisted of workshop activities, field, lab, and evaluation studies, and the design and implementation of the learning pathway and the learning elements. Workshops fell into one of the following three categories: prototype development workshops, substantive subject-orientated workshops, and evaluation workshops. The workshop format allowed for effective knowledge sharing and collaboration across the different disciplinary domains involved in the xDelia project. The studies we have conducted in xDelia can be categorised as either lab-based studies (to test out for instance a concept, hypothesis, or game in a controlled setting, typically with student populations and in some cases with investors), field studies (designed to validate the findings from the lab-studies in a more realistic setting and with investors), and evaluation studies (mainly user experience studies built around other lab or field studies and conducted in parallel). Over the three years, we conducted around 35 studies in which a total of 1422 students and 793 traders and private investors participated. In addition, we conducted a few larger scale studies such as the disposition effect study (IFS-3) with 3,000 investors, the Dutch Household Panel Survey on financial capability and emotion regulation with a population of approx. 5,500 subjects, and study on financial capability, emotion regulation and impulse buying as part of the BBC LabUK 'Big Money Test', with over 100,000 participants.

## THE WORK UNFOLDING

During the first year of the project, much of the knowledge sharing activities and the collaborative decisions about how to drive the project forward arose out of workshops and meetings. During these activities, partners pooled their knowledge and expertise to design a first batch of exploratory studies and worked towards effective ways to collaborate across the different disciplines and at a distance. A principal goal of the exploratory studies was to identify valid and robust measures of arousal and emotion regulation, and appropriate and practical methods for collecting data and feeding these into the games for emotion regulation skills training.

Previous research suggests that emotion plays an important part in financial decision-making. Evidence we gathered during exploratory work in the first year confirmed the importance of emotion regulation in financial trading. During this period, we decided that the xDelia learning intervention should target the disposition effect (DE), a common emotional bias that we could measure in the lab and in the field. The DE is a financial decision bias whereby investors hold on to losing positions for longer than to winning positions. That is associated with poorer investor performance.

In the course of the second year, we ran a series of field studies with professional traders working for two different investment banks. These studies demonstrated that less experienced traders had lower ability to regulate their levels of emotional arousal during stressful trading than more experienced traders (Fenton O’Creedy et al., forthcoming). The fact that more experienced traders had learned to regulate their emotions pointed to emotion regulation as a skill that could be trained. These studies also demonstrated that HRV provided a good measure of emotion regulation that could be measured and recorded accurately in the field.

At the same time, studies using physiological sensors with student participants identified mindfulness as a valid technique for managing emotional arousal. A set of learning elements were designed that would work standalone or in combination to support the development of emotion management skills. Learning elements included serious games which cause emotional arousal in players and feed this physiological information back into the game play. We also developed complex algorithms that would calculate the DE from real-world trading history as well as from performance in a financially realistic game, the two index game.

By the end of the second year, the xDelia Learning Pathway was taking shape. Building on the findings from the first two years, the focus in the third and last year shifted toward the development and testing of the learning elements, and the design and implementation of the xDelia Learning Pathway. The learning pathway together with the learning elements aimed at developing better emotion regulation skills for investors, and at the transfer of these skills to trading practice.

The various elements that comprise the learning pathway were trialled through numerous lab and field studies conducted during the last year of the project. As soon as the individual elements had been tested with students, sections of the xDelia Learning Pathway were put together and trialled with real investors at investor conferences, in special workshops, and through survey instruments. Taken together, our studies provide much support for the validity of the xDelia learning approach and the various learning elements.

## Evaluation of project outcomes

### WHAT WE HAVE EVALUATED

We have evaluated individual elements of the xDelia Learning Pathway and, where possible, combinations of these elements in 35 lab, field, and evaluation studies involving 1422 students and 793 traders and private investors. We have targeted two key themes with these evaluations: evaluating effects of the learning elements and evaluating user perceptions of the learning experience.

Data on user experience has been gathered through a combination of surveys and interviews with participants in trials of learning elements, and has included data on usability; user engagement and enjoyment; and on user perceptions of learning outcomes and learning potential.

Data on effects has, where possible, been gathered through the use of randomised control design studies. In particular we have examined the effect of learning interventions on improved emotion regulation; improved mindfulness; improved interoception and body awareness; and financial decision-making behaviour (including susceptibility to the disposition effect.).

### WHAT WE HAVE FOUND

- Taken together, our studies provide much support for the validity of the learning approach and the learning elements which make it up.
- We have very positive feedback from investors suggesting our learning approach to be engaging, enjoyable and a good basis for learning.
- There is good evidence for the effects of the learning interventions in achieving proximal goals of improving emotion regulation, mindfulness and interoception.
- Our studies support the value of our sensor based games in diagnosing emotion regulation capabilities and the value of the Two Index Game in diagnosing a propensity to a disposition effect.
- We show a significant impact of training on disposition effect as measured in real world trading behaviour.

### EVALUATION FRAMEWORK

The evaluation activities of the xDelia project have been guided by the macro-level Design and Evaluation (D&E) Framework, which is also an output of this project. A micro-level evaluation tool, the M3 Framework, complements this framework, and assesses and interprets the user experience data of the xDelia Learning Pathway and learning elements.

The D&E framework was designed progressively over the first two years of the project to facilitate the evaluation of project interventions and collaborations. It fulfils a dual function. On the one hand, it acts as a model for the design of effective project interventions, clarifying the interdependent relationship between the research questions, research interventions, the evaluation, and the mechanisms by which the findings from the evaluation are fed back into the project to inform future interventions. On the other, it acts as a lens through which we reflect on what happened during the intervention, supporting collaboration by involving the stakeholders as reflective evaluators, and feeding the findings back into the project on an ongoing basis.

The M3 framework organises the detailed evaluation of the xDelia Learning Pathway and learning elements at the level of learning outcomes. Often, several learning elements work together to contribute to a single learning

outcome. In the same way multiple learning outcomes can feed into each overall learning objective. The M3 framework makes these complex relationships explicit and visible, clarifying how the learning elements are linked to the learning objectives and learning outcomes that need to be evaluated. The specific evaluation instruments – interviews, focus groups, surveys, and so on – have been designed based on this detailed analysis of the evaluation requirements.

## THE CONCEPT AND PURPOSE OF THE LEARNING INTERVENTION

The xDelia project is concerned with developing approaches to improving financial decision-making. The primary target group is investors who trade their portfolio regularly, typically via online trading platforms. This is a large and increasingly economically important group around the world. Such traders invest their own funds in speculating in markets for financial assets. Most national and trans-national regulatory regimes are concerned with the need to ensure that citizens participating in such activities are well informed about risks. Thus we focus on adult learners who have typically engaged in a significant amount of self-directed learning to support their trading practice and who tend to be highly motivated to engage in learning which may improve their investment performance.

### The challenge of reducing investor decision bias

To date, efforts of investor education focus primarily on knowledge transmission approaches and on reasoned explanation of risks. However, there is substantial and growing evidence that much financial decision-making behaviour is strongly affected by emotion and that financial decision-makers are prone to behavioural biases which lead to unplanned risks and problems in implementing rationally planned investment strategies (Fenton-O'Creevy et al., 2011; Weber & Johnson, 2009). This is also substantially evidenced by the events leading to the recent global financial crisis, which implicated the poor decision-making of both institutional and private investors.

A particular concern is to develop learning approaches which improve participants' capacity to avoid common decision traps and biases. In doing, so we need to overcome the problems which have plagued previous approaches to 'de-biasing'. Many forms of de-biasing training have been, at worst, counter-productive and at best had very limited impact even in lab settings (Bazerman, 2002; Davidson et al., 2003; Fischhoff, 1982; Lilienfeld, Ammirati, & Landfield, 2009). Similarly, decision-support systems which seek to aid decision-makers in avoiding biases have been largely unproductive because they often make decision processes unnatural and difficult, and because they typically ignore the role of expertise in complex domains and risk preventing the development of expertise (Yates et al., 2003; Klein, 2009).

A key problem with de-biasing training approaches is that human capacity for self-monitoring and effortful cognition is limited and is rapidly depleted (Baumeister et al., 1998). Attempts to reduce biases by learning about biases and engaging in self-monitoring, rapidly come up against human cognitive limits. Although many cognitive biases identified in laboratory studies either disappear in naturalistic settings or turn out to be adaptive (e.g. Gigerenzer, 2000, 2004), certain biases such as the disposition effect turn out to be remarkably robust in both laboratory and field settings with demonstrably maladaptive effects on decision-outcomes (e.g. Fenton-O'Creevy et al., 2003; 2005).

While expert professionals remain susceptible to these decision biases, experts are often less prone to the effects of such biases when making decisions in their domain of expertise. Evidence from our field studies conducted with traders and investors shows for instance that the disposition effect is lower for more expert traders (Yee & Lins, 2011b). Also, against the background of convincing evidence that some biases may represent the inappropriate applications of heuristics in contexts where their use is not 'smart', we argue that experts in those domains are often marked not by their lesser use of heuristics but by the deployment of more appropriate heuristics and more nuanced recognition of contextual cues. Thus while we do have a focus on

reducing maladaptive biases in financial decision-making our benchmark for adaptive behaviour is not, as in the judgement and decision-making literature, a normative model of optimally (or boundedly) rational behaviour. Rather we take as our benchmark the behaviour of expert traders.

What does this concretely mean in terms of designing a workable learning intervention? While we do have a focus on reducing maladaptive biases in financial decision-making, the challenge in xDelia has been to develop learning approaches that do not simply depend on increasing self-monitoring behaviours, that integrate well with practitioners' informal learning, and that also support the process of developing expertise.

## Developing an alternative approach

As we note above, prior approaches to de-biasing training have been especially ineffective in transferring learning into real-world settings. In contrast our approach to learning to avoid systematic biases in financial decision-making recognises first, the importance of enhancing domain-specific task feedback and, second, the role of emotions in mediating intuitive, fast, and automated 'System 1' decision-making.

In particular a wide range of decision-biases can be shown to be underpinned by emotion processes (Loewenstein & Lerner, 2003) and a central proposition of the xDelia project is that maladaptive behaviours in financial decision-making can be reduced through more effective regulation of emotions. We have a particular focus on biases in financial decision-making which have the following characteristics:

- the bias has been demonstrated to be significant in naturalistic settings as well as in the laboratory
- there is reason to believe that emotions play an important role in the operation of the bias and
- the bias is tractable to detection at the level of the individual, for example, through the analysis of past trading decisions.

To develop and establish a 'proof of concept' for this approach, we have chosen to focus on one particular behaviour which fits the above criteria: the disposition effect. The disposition effect is the tendency to hold assets which would sell at a loss for longer than assets which would sell at a gain. In colloquial terms an investor who suffers from the disposition effect cuts their wins short and runs their losses too long. This behaviour seems to arise out of the desire to avoid the emotional pain of realising a loss (Frydman, Barberis, Camerer, Bossaerts, & Rangel, 2011). So long as the investor does not convert a paper loss into a realised loss they can console themselves that 'it will probably increase in value again'. Such behaviour is of course rational if investors have hedonic goals as well as financial goals. They may be trading off financial outcomes against a reduction in emotion pain. Our intention, is not to suggest that it is not legitimate for investors to have hedonic as well as financial goals. Rather the intention is to provide greater choice in how those hedonic goals are met so as to be able to meet both financial and hedonic goals together.

The disposition effect can be reliably demonstrated in laboratory experiments but there is also a very significant body of research which shows the disposition effect to be remarkably robust and to characterise trading patterns across a wide range of financial decision-making contexts and at different decision-making time horizons (Barberis & Xiong, 2009). Given a sufficiently large trading history, it is possible to analyse the trading record of an individual investor to characterise their propensity to a disposition effect. As part of the project we have developed an approach to synchronous measurement of the disposition effect of individual investors both through analysis of trading data and in game play (Yee & Lins, 2011b).



The disposition effect is widely understood to be mediated by emotion processes (Lee, Kraeussl, & Paas, 2009; Thaler, 1999). The recent literature on emotion regulation makes it clear that humans do not just experience emotions; we actively regulate them (Gross, 2002; Gross & Thompson, 2007). Recently, empirical research has begun to address the role that emotion regulation processes play in individual susceptibility to biases. For example, a large scale field study of investment bank traders showed important differences between novice and expert traders in emotion regulation strategies and showed many traders and their managers to be much concerned with the regulation of emotion to avoid the biasing effect of strong emotions on trading decisions (Fenton-O'Creevy, Nicholson, Soane, & Willman, 2005; Fenton-O'Creevy et al., 2011). In our learning pathway we have adopted both questionnaire-based and physiological measures of emotion regulation to provide feedback to participants on their regulation of their emotions.

Our sensor-based games target improved emotion regulation through three pathways: first, as an arena to practice emotion regulation techniques (for example mindfulness); second by providing opportunities to practice regulating arousal levels; and third by targeting improved self-awareness of internal states (interoception). Interoception is sensitivity to internal physiological stimuli and is an important element in our self-awareness of experienced emotion (Wiens, 2005). Recent research demonstrates the role of interoception in drawing emotions into greater awareness and reducing emotional arousal (Herwig, Kaffenberger, Jäncke, & Brühl, 2010).

Whilst much of our work in xDelia has focussed on the disposition effect, it is worth noting here one way in which our thinking has evolved in conversations with the many private investors we have engaged with in the course of our studies. The very large majority are very concerned with the impact of emotions on their decision-making and discussions of emotions and their effects make up a significant proportion of the traffic on an online trader forum we have monitored. However, whilst there is some concern with the impact of individual biases such as the disposition effect many traders are preoccupied with a broader concern: namely that it is a common experience to have a carefully planned strategy which they are then unable to implement because of the intensity of their emotions. This seems common to both private investors and professional traders. One investor summed it up as follows *"I thought it was my dirty little secret how emotional I get about my trading . . . I execute trades perfectly when I try them out [in simulation with nothing at stake] but as soon as I am trading with serious amounts of money it all goes tits up, I panic and pull out early or freeze and stay in too long and watch it all disappear into a black hole"*.

Thus while the disposition effect has provided a useful focus for the project, the benefits of improved emotion regulation when trading may have most impact in relation to this broader category of emotion effects.

## The target group

The target group for the xDelia Learning Pathway is primarily private investors, who are involved in decision-making concerning risks directly related to their own wealth and ownership of assets and who trade their own portfolios online on a regular basis; as distinct from professional traders, who work professionally as decision-makers concerning the risk of a financial institution<sup>2</sup>.

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<sup>2</sup> We should not overstate this difference since bonus structures mean that professional traders also typically have a significant financial stake in their trading performance.

While many investors trade their assets infrequently, with long time horizons, an economically important and growing subset of investors trade frequently, using online trading platforms provided by firms which facilitate investor participation in financial markets. Such clients may be categorised as investors, with a limited set of tools and unprivileged information flows concerning the market. These individuals are largely self-driven, transacting on a trading platform, and although it is expected that they are quite qualified through their familiarity and experience with financial markets, the nature of trading, and the risks involved in participating in investment and speculation, they typically have no institutional experience or formal training in this field. It is this sub-set of private investors who trade online that are the primary focus of the xDelia Learning Pathway and its elements that we describe in this document.

We know from xDelia exploratory studies, that investors using trading platforms are often highly motivated to acquire knowledge and skills which may give them an advantage relative to other market participants. Learning materials already provided by trading platform providers are well used as is the opportunity to use trading platforms in simulation mode. Interviews with investors<sup>3</sup> suggest the following common modes of learning: self-teaching, learning in a social setting, learning from experience, and seminars/workshops.

Broking organisations have an interest in the provision of learning resources and in providing support to clients who wish to improve their trading competence. However, such support and resources have to be cost effective and scalable across many thousands of clients. Thus a challenge for xDelia has been to construct learning approaches which are scalable for large groups of investors trading online and which integrate well with investors existing self-guided approaches to learning<sup>4</sup>.

## The xDelia learning approach

The xDelia learning approach is an integrated approach that frames learning objectives at three levels:

**Level 1: Diagnosis and feedback** – Understand the disposition effect and emotion regulation strategies and how they relate to investor trading. And improve awareness of own profile in relation to disposition effect, habitual emotion regulation strategies, and propensity to defensive emotion regulation

**Level 2: Skill development** – Develop skills in recognising and avoiding the disposition effect and in effective emotion regulation in a learning environment

**Level 3: Transfer** – Support transfer of skills from the learning environment into the trading practice context

To achieve these outcomes, we engage participants in the acquisition of propositional knowledge, provide opportunities for feedback, provide a learning environment for skill acquisition and practice, and provide a supported approach to transfer of skills into participants' real-world practice of trading.

During year 3, the primary focus of research and design activities has been to formulate and implement a learning intervention that incorporated serious games and bio-feedback, to help private investors acquire better

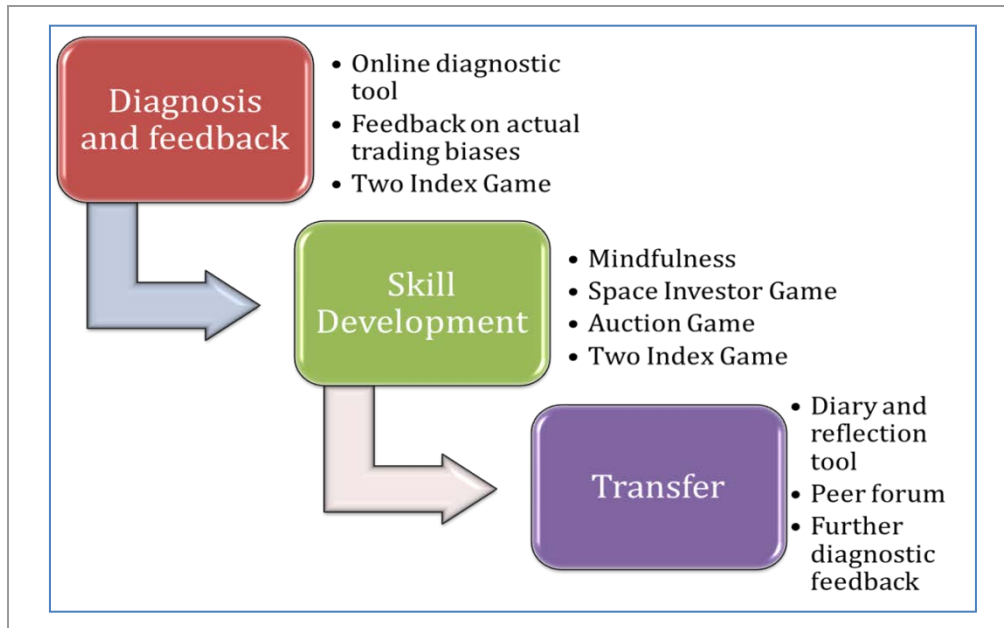
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<sup>3</sup> See project reports on exploratory studies and stakeholders available at [www.xdelia.org](http://www.xdelia.org)

<sup>4</sup> Although we are clear about our target population, not all evaluation has been carried out using members of this group. Given problems of access and the difficulty of properly randomised control studies with investor subjects, initial studies were better carried out using student populations.

emotion regulation skills, and support the transfer of these skills to their real-world trading context. The ultimate goal is to improve their financial decision making and trading performance under pressure through better management of emotions. The learning intervention needed to provide support for informal, self-directed learning. This support therefore had to be both engaging and relevant to the learning needs of private investors,

The design of the learning intervention was guided by the analyses and findings from studies conducted during the first two years of the xDelia project. During year 3, these findings drove the development of a coherent learning intervention called the xDelia Learning Pathway.



*Figure 3-1: The xDelia pedagogical framework*

The xDelia Learning Pathway is founded on informal learning principles (Burbules, 2006, Livingston, 1999) and consists of a flexible set of learning elements designed to work together to teach investors strategies to manage their emotions and thereby support them in making better financial decisions under stress. Each learning element is standalone, so that learners can mix and engage with these elements in ways that best suits their learning needs. Combining these elements allows for diagnosis and feedback on behavioural biases through games and through real world trading; learning and practicing emotion regulation strategies in a game environment; practicing emotion regulation strategies in the practice context; and support for reflective practice.

We are clear that didactic, knowledge-focused learning approaches to de-biasing have largely failed in the past (Bazerman, 2002; Fischhoff, 1982; Lilienfeld et al., 2009). However, that does not mean that we entirely reject the utility of didactic approaches. First, some element of knowledge transmission is necessary to support the other approaches we espouse. For example feedback on susceptibility to a disposition effect or training in improving emotion regulation is unlikely to be effective without an understanding of the nature of the disposition effect and the meaning of emotion regulation. Second, the impact of didactic approaches on real world practice should be significantly enhanced to the extent that the learning is brought alongside and placed in the context of the specific domain of practice (in this case investors trading on a trading platform).

The learning approach can be broken down into three key aspects: diagnosis and feedback, skills development, and transfer (see Figure 3 1). While the diagram represents this as a linear pathway, we would emphasise that we expect that in practice it should be quite iterative, with participants returning to earlier diagnostic and skill development phases as they work on transferring these skills into the trading context.

## **DIAGNOSIS AND FEEDBACK**

Feedback is an important component of any learning process. Yet, there is considerable evidence that many feedback interventions are ineffective (Kluger & DeNisi, 1996). Simple feedback on outcomes is particularly problematic when tasks are complex or important antecedents of outcomes are beyond the control of the feedback recipient. This is very much the case for the trading tasks faced by investors. Indeed we can understand biases such as the disposition effect as arising out of failures in the utility of outcome feedback for investors. In contrast to outcome feedback, which concerns the accuracy or correctness of response, cognitive feedback concerns the how and why that underpins the outcomes. There is evidence that properly designed cognitive feedback has significantly greater utility for learning than outcome feedback in complex real world domains. Some of this evidence is specific to trading tasks.

Thus our position is that outcome feedback will be most relevant where we have been able to extract relatively simple aspects of expert performance which can be trained to some extent in isolation from other task elements. Where we are concerned with more holistic tasks the focus should be on feedback with explanatory power. At the level of the whole investment task feedback on biases and emotion regulation has explanatory power and, research evidence is beginning to suggest, predictive power, and can be understood as an instance of cognitive feedback, especially when teamed with structured opportunities for reflection.

### *Feedback on biases*

There are two approaches to provide feedback on the extent to which investors display key biases such as the disposition effect. Where investors have an existing accessible track record of trading, it is possible to analyse past behaviour to directly compute the disposition effect. Where investors are only just beginning to trade or where prior trading records are not easily accessible, biases can be detected and diagnosed through ecologically valid tasks implemented as trading games. We make use of both approaches in our learning interventions. We have designed algorithms and data management approaches to detect the disposition effect on the basis of investors trading history and have designed a game (the Two Index Game) which provides a simple trading simulation game in which the disposition effect can be reliably elicited and diagnosed.

### *Feedback on emotion regulation*

A key element of our approach is to support improvements in financial decision-making by supporting the enhancement of emotion regulation skills. We provide feedback on emotion regulation in two ways. First, we have developed a diagnostic online questionnaire approach which provides feedback on participants' habitual emotion regulation strategies. Participants receive customised feedback and didactic learning materials on emotion regulation via text and video. The use of online questionnaire instruments can help with self-diagnosis of habitual emotion regulation strategies. Secondly we have designed games in which performance depends on the ability to manage arousal. These games can be used in diagnostic mode, as well as in the development of emotion regulation skills. Thirdly, participants who follow the xDelia Mindful Trading Training have access to a

web-based software tool to facilitate the monitoring of progress on mindfulness skills throughout the training (xMedit-Mate).

## **SKILL DEVELOPMENT**

Humans often over-learn from single episodes; for example a prior study (Fenton-O'Creevy et al., 2011) found trader managers to be much concerned with avoiding bad learning outcomes when novice traders experience large losses or large gains early in their careers. Serious games can then potentially provide a safer and more playful environment for learning. Such games can be brought together with informal practice-based learning in a cycle of critical reflection.

### *Developing emotion regulation skills*

Specifically we use physiological feedback on arousal during games to make performance depend on managing physiological arousal. Since management of physiological arousal and awareness of physiological state is closely related to effective emotion regulation this should support development of emotion regulation skills. We have developed two games, Space Investor (a first person shooter) and the Auction Game (a simple financial decision-making game) to fulfil this function. In both games, game difficulty is linked to arousal level as measured by a heart-rate monitor. High performance depends on managing arousal in the face of arousing game play.

These games support development of emotion regulation skills in three ways. First, they provide an environment in which management of arousal levels can be practiced and rewarded. Second, by directing attention to the participant's own physiological state they encourage improved interoception (awareness of internal physiological state); there is empirical evidence for a link between interoception and perception and regulation of emotion state (Damasio, 2000; Wiens, 2005). Third, they provide a context for the practice and consolidation of emotion regulation approaches developed in other contexts (for example mindfulness training). In-game feedback on arousal to improve interoception is complemented by post-game feedback on regulation of emotions as measured by heart rate variability.

### *Mindfulness training*

We have also drawn on work on mindfulness approaches (Davidson et al., 2003; Kabat-Zinn, 2003; Kabat-Zinn et al., 1992; Peterson & Pbert, 1992) to improving emotion regulation. Mindfulness approaches use meditation based techniques to enable practitioners to develop the capacity to notice unhelpful thoughts and feelings and allow them to pass without being drawn into acting on them or continuing with them. We are building here on established practice in a domain where there is significant evidence of success in enabling individuals to learn more effective emotion regulation strategies - cognitive behavioural therapy. The most recent approaches to CBT draw on the Buddhist tradition of mindfulness (Baer, 2003; Kabat-Zinn, 2003) and have had considerable success in using mindfulness training as a foundation for more effective regulation of emotions and behaviour (Davidson et al., 2003; Kabat-Zinn et al., 1992).

Our innovation here is to translate key elements of mindfulness into the domain of financial decision-making and developing approaches to online delivery of mindfulness training that can be delivered via a learning space attached to a trading platform. We have therefore evaluated the use of mindfulness training in conjunction with the sensor based games and developed an approach to mindfulness training, including two online applications xMedit-Mate and xHale Athlete, that can be delivered via a web based learning space linked to a trading platform.

## TRANSFER

A core problem for the use of games for learning is that of transfer. How do we ensure that learning in a game environment transfers beyond the bounds of the game? The first strategy involves attention to ecological validity. Do elements of game performance sufficiently mimic key elements of work performance to make transfer realistic? The second strategy concerns a learning framework which brings game based learning alongside feedback on performance in the practice setting (trading or investing). Skills are first developed and practiced in a game setting before being practiced (with support and feedback) in the trading or investment setting.

Learners receive feedback in both the game setting and practice setting. They have opportunities for learning in both spheres. The challenge is to support translation of learning from the game domain to the practice domain. The key is to support and enable critical reflection on practice drawing on the insights from game based learning. Such reflection can be informed by structured approaches to writing down and reviewing trading strategies, accompanied by structured reflection about emotional state and management of emotion while making key decisions.

We have designed and evaluated a diary based approach to supporting transfer. This includes simple tools for recording and reflecting on emotion state (c.f. Oglvie & Carsky, 2002). For example, such approaches may highlight when behaviour is inconsistent with planned trading strategy at a period of significant anxiety and provide the opportunity to review how this came about.

## THE XDELIA LEARNING PATHWAY

The xDelia Learning Pathway is an informal learning intervention consisting of learning elements that learners can undertake at a time and location that suits them, typically over a period of between 6 weeks and 6 months. It uses pedagogical principles of dialogic and reflective learning implemented through computer-delivered learning elements (questionnaires, games, online forum, online diary tool). This allows the learners to choose the learning context, manner, and extent to which they engage with the learning elements. The xDelia Learning Pathway is designed to be undertaken over a period of time. Once learners have completed the initial Diagnosis and Feedback stage, they can engage with the Skill Development elements in any order, and the diary and peer forum are designed to support the learners' journeys along the xDelia Learning Pathway and beyond.

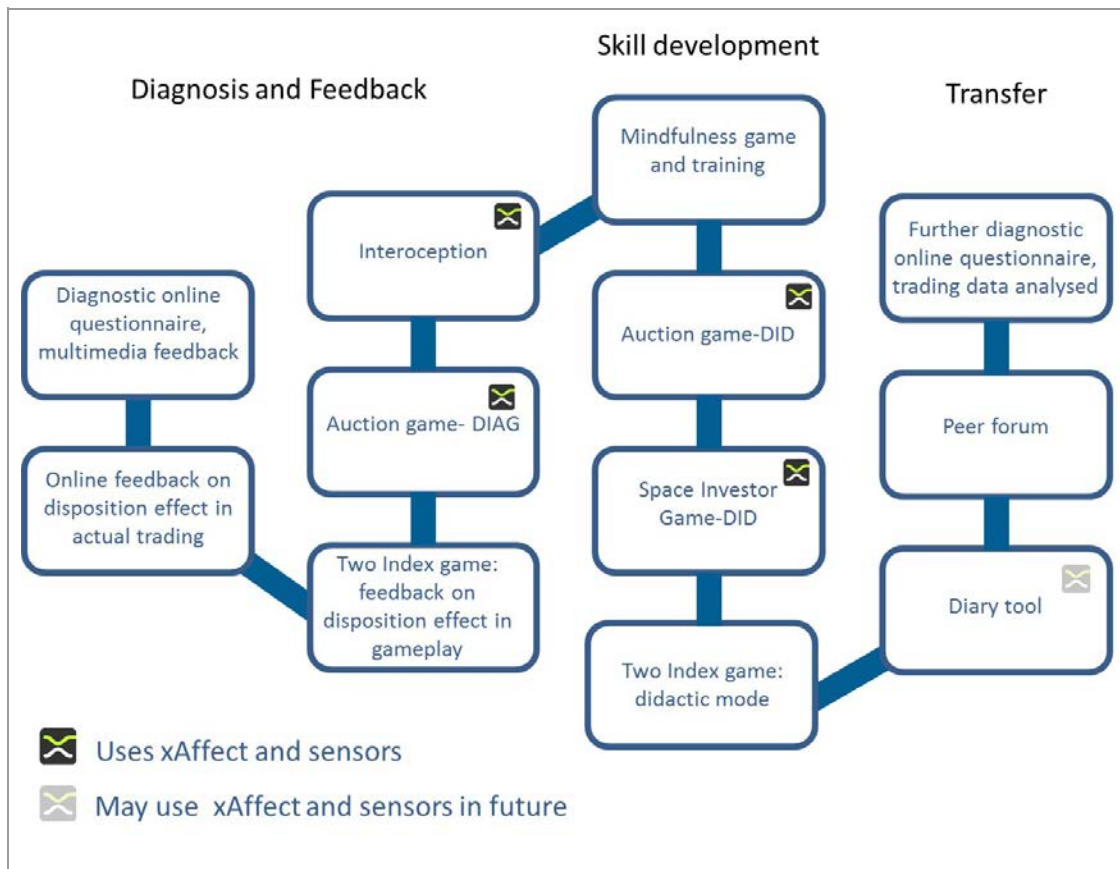


Figure 4-1: The idealised xDelia learning pathway

In section 3, we outlined our overall learning approach. In this section and the next we provide an account of the pedagogic role of each of the learning elements that we have implemented. To do this we first describe an idealised learning pathway which contains all of these elements and explain how they contribute to diagnosis and feedback, skill development, and transfer. We say 'idealised' because the target audience is composed of self-directed, self-motivated learners. It is neither appropriate nor possible to impose a fixed learning route on them. Individuals will vary in learning needs and approaches to learning and may choose to adopt some but not all of the learning elements. It is also our belief that these learning elements may have a broad range of uses in different training settings, and we do not wish to imply that other learning pathways are not possible.



## The idealised learning pathway

In section 3 we described three main stages of the learning pathway: diagnosis and feedback, skills development, and transfer. In this section we break this down in more detail to show the role of each of the learning elements. In Section 4, we describe the pedagogic role of each of the learning elements in more detail. Figure 4.1 provides an overview of the roles played by each element in the learning pathway.

### DIAGNOSIS AND FEEDBACK

The pathway starts with collection of diagnostic information on the participant's propensity to the disposition effect and her approach to emotion regulation. There are two aims:

- to develop the participant's self-awareness in relation to the disposition effect and emotion regulation approaches
- the diagnosis process provides a vehicle for the delivery of propositional knowledge in relation to the disposition effect, the role of emotion in trading biases, and emotion regulation strategies and how they relate to investor trading. This should increase participant engagement with the concepts by making them highly personally salient

Diagnosis is achieved through:

**A diagnostic online questionnaire** – Participants are asked to complete an online questionnaire on emotion regulation strategies, which identifies the emotion regulation strategies they habitually employ and their habitual levels of mindfulness (ERQ and Mainz coping inventory).

**Online feedback on the disposition effect they show in their actual trading** – Where investors have an existing accessible track record of trading, it is possible to analyze trading behaviour to diagnose the extent to which they display key biases such as the disposition effect. xDelia partner Saxo Bank have devised algorithms to automatically calculate the disposition effect from trading data.

**Multimedia feedback on emotion regulation and disposition effect** – Based on results from the emotion regulation questionnaire and trading history, participants are given personalised feedback on their biases, in the form of text and videos<sup>5</sup>. Alongside feedback, the investor is given access to multi-media didactic materials on the disposition effect and emotion regulation and the likely meaning of the feedback in relation to their own investment practices.

**Two Index game: feedback on disposition effect in game play** – Playing the 'Two Index' trading game (described in section 5.5 below) will also enable the diagnosis of the participants' propensity to the disposition effect. This game uses a simple trading task under time pressure to induce a disposition effect in players. Played in diagnostic mode, the game can gather information about the extent to which the participant is susceptible to the disposition effect. This will be particularly useful to help diagnose investors without available trading history.

**Interception** – Using an ECG sensor (see section 5.2.5 below) and the xDelia physiological framework (see section 5.2 below), participants are asked to estimate their heart rate as a means of identifying how

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<sup>5</sup> See Appendix C, Section 9.2 for examples of transcripts from video feedback



well they are aware of their internal physiological condition. A standardised comparison between actual and estimated heart rate over multiple trials provides a measure of interoception. We have also trialled a body-vigilance questionnaire.

**Auction game (diagnostic mode)** – The Auction game, similarly, varies game difficulty according to player arousal. The game though involves a financial decision-making task. The aim here is to bring the training context increasingly closer to the trading context. Playing the Auction Game in diagnostic mode while wearing an ECG sensor and gathering physiological data via the xDelia physiological framework will enable trainers to establish to what extent a participant becomes aroused, and can regulate their arousal levels, while playing a simple financial simulation. This enables an evaluation of subjects performance and corresponding physiological responses (measured in deceleratory heart rate response) to gains, foregone gains and losses. This allows matching physiological traits that could be related to individuals' exposedness to decision biases such as the disposition effect.

## SKILL DEVELOPMENT

Having diagnosed a participant's susceptibility to the disposition effect and their ability to regulate emotion, the xDelia Learning Pathway provides the following tools to enable skill development:

**Two Index game** - In this stage the Two Index game becomes a learning space where the participant can try out and get feedback on different strategies for avoiding the disposition effect. In a first iteration they can play the game multiple times and experiment with monitoring and modifying their own behaviour. In diagnostic mode the game provides post-hoc feedback on disposition effect. In didactic mode players can see a gauge which gives real time feedback on the level of disposition effect they are exhibiting. This game can also be used as a play-space where participants can practice approaches to emotion regulation whilst engaged in a trading like task.

**Space Investor game (didactic mode), Auction game (didactic mode), Mindfulness game xHale Athlete and Mindful Trading Training, including the xMedit Mate app** – In these stages participants get the opportunity to engage with learning elements which support the development of enhanced emotion regulation. Two approaches are involved here: a) mindfulness training supported by a mindfulness game and training tool; b) the use of the Space Investor game and Auction Game in didactic modes. In these modes the games display a gauge which shows current arousal level as an aid to management of arousal.

## TRANSFER

A number of tools support transfer to real world contexts of learning that takes place in the game environment:

An online diary tool integrated with the trading platform supports a structured approach to writing down and reviewing real world trading strategies including reviewing emotion state and emotion regulation. The focus on writing down trading strategies and on reasons for changing them provides a commitment mechanism which improves self-monitoring of emotion driven decisions. The collection of emotion state and emotion regulation information provides the opportunity for critical reflection on the transfer of learning into the trading setting.

The diary tool is linked to template-based structured reflection tasks. Output from these tasks is stored in the diary tool. This provides opportunities to review progress in a structured way, including additional feedback opportunities on disposition effect and emotion regulation. The diary tool allows the capture of multiple feeds of data, such as a snapshot of market behaviour at the time of diary entry. The diary tool may in future also

allow physiological data to be captured, enabling the participant to use physiological data as a marker for trades to pay particular attention to.

The need to produce highly scalable approaches to learning for the target audience precludes a personal coaching approach. However, transfer should be supported more effectively with opportunities for engagement with peers involved in similar learning. Saxo Bank is implementing forums with tools to support development of peer learning groups interested in such learning.

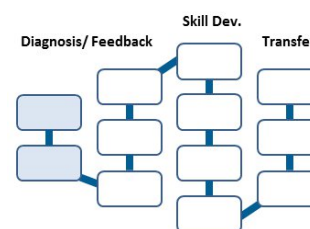
## ELEMENTS OF THE LEARNING PATHWAY

The xDelia Learning Pathway consists of a number of elements that may be used in different combinations depending on the envisaged training journey, or on the constraints of the learning environment, such as whether learners have access to physiological sensors. We expect that because investors often are experienced self-learners, they may pick and choose different elements to construct their own customised learning pathway, choose not to use all elements, or revisit some elements multiple times.

In the sections below, we list for each learning element the studies in which they have been evaluated.

### Online diagnostic tools

At the start of the learning pathway, participants are asked to complete an online emotion regulation questionnaire to understand their habitual emotion regulation and coping strategies (vigilance versus avoidance when faced with ego threats). For participants who trade via the Saxo Bank Trading Platform, the diagnostic tool can conduct an automatic analysis of their trading history using algorithms and data management techniques developed by Saxo. The data from these sources allows the calculation of participants' tendency to display the disposition effect and how they manage their emotions.



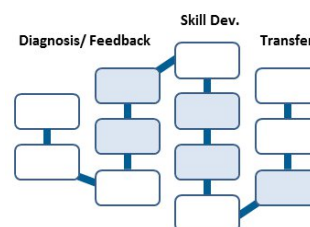
On completion of the questionnaire, the participants are presented with video and written feedback via a web-based interface. Participants are given two sets of customised feedback, in response to their calculated emotion regulation and disposition effect results. The system will maintain a persistent record of participants' results, so they are able to return and review them at a later date.

**Where used:** Diagnosis and feedback

**Where evaluated:** TIG-1, S-M1/2. Further details can be found in D9-2.3.3, and D20-6.3.3.

### The psychophysiological monitoring framework

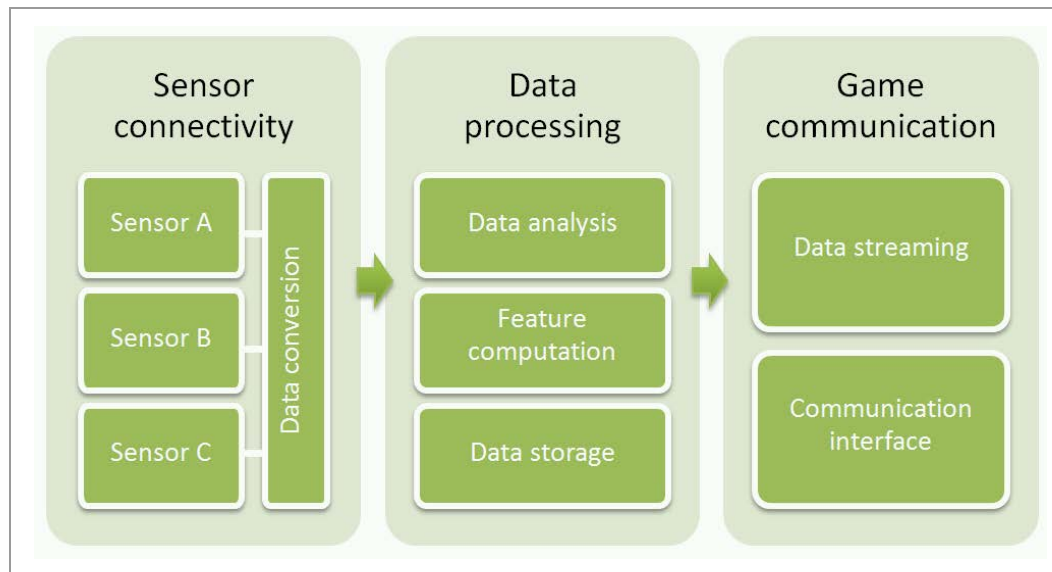
At the heart of the xDelia training approach is the capture of psychophysiological data, specifically electrocardiographic (ECG) data on heart rate variability. Heart rate variability provides a measure of the moment-by-moment interaction of the sympathetic and parasympathetic nervous systems of participants yielding information about regulated emotion responding. Identifying the ability of participants to undertake effective emotion regulation provides diagnostic information. Presenting live emotion regulation data to the participants while they are engaging with learning elements in didactic mode during the skill development phase of the learning pathway enables them to try out and practice techniques for emotion regulation, and transfer them to real world practice.



To generate real time and post-hoc feedback in a more systematic and robust way, we developed a modular psychophysiological monitoring framework – xAffect ([www.xaffect.org](http://www.xaffect.org)) – in which sensors and games can be linked together via specialized data processing components. This provides us with a highly configurable and

flexible set of tools adapted to the varying demands of the training context and the investor learning pathways (Figure 5 1):

**Sensor connectivity** – The xAffect software comes with a hardware abstraction layer which can easily be configured to connect to various commercial physiological sensor systems such as the movisens ekgMove device currently used to collect ECG data for xDelia learning tools. Other systems such as the Variport-e and a pressure sensitive mouse can also be used. Currently the Space Investor game, the Auction Game and the Interoception Tool use physiological sensors and the psychophysiological monitoring framework.



*Figure 5-1: The psychophysiological monitoring framework (data flow)*

**Data processing** – The signal processing algorithms use the sensor data to compute features such as the arousal level of a participant playing an xDelia game. The data processing is designed in a very flexible way so it can easily be extended by adding further algorithms. Currently data processors include: ECG to R-peak, R-peak to HR, HR to arousal, HR to HRV, HR + PPG to PTT, Mouse button press, EDA.

**Game communication** – The features which are computed by the xAffect software are then transmitted to the learning interventions. The interface to the learning intervention components is designed such that the information from the xAffect software can easily be integrated into the games to influence the course of the game. For example, if the participant's heart rate rises, this information can be passed to the game to make it more difficult to play.

**Data management framework** – The data management framework provides an environment for the evaluation of the data collected during the game play. This includes the management of the computed features in combination with the data from the game component. Combining these data allows us to evaluate various hypotheses about interrelations between a participant's behaviour during the intervention and the changes in her physiology and thus provide additional evidence for the effectiveness of the intervention.

**Sensors** – The xDelia Learning Pathway includes elements that use ECG data to measure a subject’s arousal (the Interoception Tool and the Space Investor and Auction Game in both diagnostic and didactic modes) and provide real time input to game play (Space Investor game and Auction Game in didactic mode). This ECG data is supplied by sensing devices containing ECG sensors. For the xDelia Learning Pathway, we use the movisens ekgMove device. This is mounted on an elastic chest strap that learners wear against their skin under their clothes

**Where used:** Diagnosis and feedback, Skill development, Transfer

**Where evaluated:** S-M3, S-M4, S-M5, S-M6, S-M7, S-M8, S-HP. Further details can be found in D9-2.3.3, and D20-6.3.3

## Interoception tool

A version of the xAffect psychophysiological monitoring framework has been developed to allow trainers to appraise participants’ interoception by identifying how accurate they are at estimating their heart rate and hence how well they are aware of their internal physiological state.

Interoception is the ability to perceive one’s body’s internal state. It can take many forms, for example awareness of a racing heart rate or intestinal sensations (Khalsa, Rudrauf, Feinstein, & Tranel, 2009). Interoception is thought to be fundamentally involved in the perception of emotional or affective events (Barrett, Mesquita, Ochsner, & Gross, 2007; Damasio, 2000).

There are two principal approaches to heart rate interoception: heartbeat detection and heartbeat tracking. Heartbeat detection involves the participant determining whether an external stimulus, such as a noise or a tone, is contemporaneous with their heartbeat sensation. This approach was deemed to be impractical for conducting studies on trading floors and at conferences as there was too much distraction from the stimulus. We therefore developed a tool that implements the second approach, heartbeat tracking, which evaluates how accurate the participant is at determining their heart rate (Schandry, 1981; Stewart et al., 2001). The tool developed is well-suited for use in field settings as well as in the laboratory.

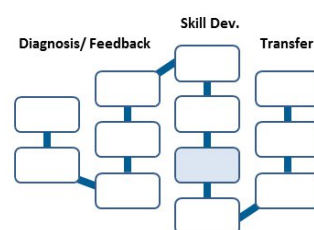
The initial use of the tool provided a baseline measure of the participant’s ability to perceive their own heartbeat. Using the tool after playing the sensor games provides a second measurement for the ability to perceive internal bodily state, which can be readily compared with the first measurement. In this way the interoception tool can be used to determine whether the intervention has had any effect on the participant’s ability to perceive their internal bodily state.

**Where used:** Diagnosis and feedback

**Where evaluated:** S-M8. Further details can be found in D9-2.3.3, and D20-6.3.3.

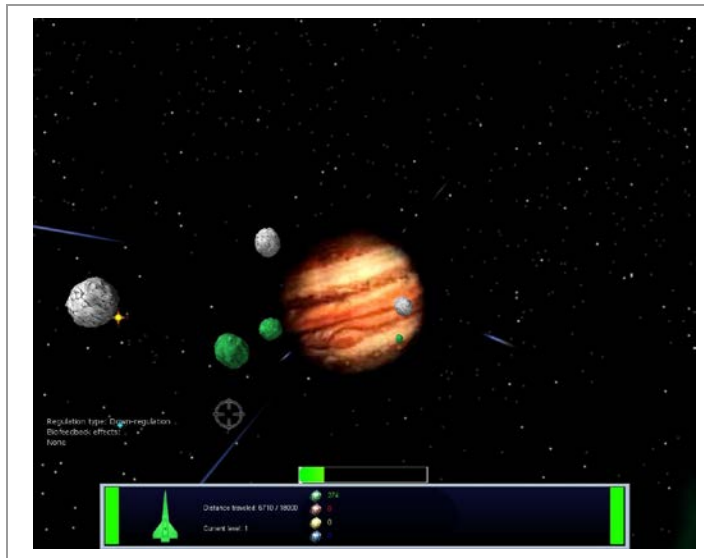
## The Space Investor Game

The Space Investor Game takes the form of an asteroid shooting game that helps to train a player’s emotion regulations strategies. Two variants have been developed: a didactic version that provides live arousal feedback to the player, and a diagnostic version, which has been used in xDelia studies for measuring



performance of control group subjects.

The purpose of the game is to assist investors in becoming aware of their own arousal state as well as training them in regulating their arousal states. Space Investor provides participants with a game environment in which to practice awareness and regulation of arousal. The game gathers biofeedback on the individual's arousal state and also requires participants to self-report their own perceived arousal level at the end of every game play level.



*Figure 5-2: Space Investor game (didactic mode) showing the arousal bar*

The participant wears an ekgMove ECG sensor, which communicates with the game via xAffect (described in section 5.2 above) and which records the arousal levels. In diagnostic mode, the game simply records how the participant's arousal levels vary. In didactic mode, the game presents the participant with visual feedback via an arousal bar and, at the same time, increases the difficulty if the participant is unable to up or down regulate arousal within specified limits. The design of the game allows for longer game play sessions. The xDelia Learning Pathway uses a version of the game that is played over five levels for approximately 15 minutes and allows participants to practice down-regulation of emotions.

### **SPACE INVESTOR GAME (DIDACTIC MODE)**

In didactic mode of the Space Investor Game, the participant obtains real time feedback on their arousal level and is asked to regulate her emotions. The game becomes gradually more difficult if the player does not succeed in keeping the level of arousal within certain bounds. At the end of each level, participants are asked to self-report their perceived arousal levels ("How stressed are you?"). These are recorded and can later be analysed, along with game play data, and arousal data (raw ECG data and computed arousal levels).

**Where used:** Skill development

**Where evaluated:** S-M3, S-M6, S-M7. Further details can be found in D9-2.3.3, and D20-6.3.3.

## SPACE INVESTOR GAME (DIAGNOSTIC MODE)

The Space Investor Game in diagnostic mode was developed to record arousal in a control group during evaluation studies. We don't anticipated that this version is going to be used in a typical investor learning journey.

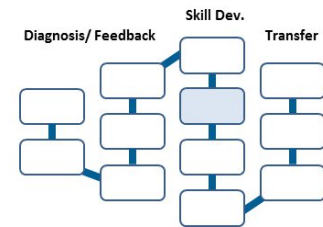
**Where used:** Diagnosis and feedback

**Where evaluated:** S-M7, S-HPb. Further details can be found in D9-2.3.3, and D20-6.3.3.

## The Auction Game

The Auction Game is a simple financial decision making game simulating a stock exchange. The participant plays the role of an auctioneer buying and selling stocks, and tries to obtain maximum profits by making the correct decisions when presented with options to either buy or sell at different prices.

The game has two versions or modes: diagnostic, where the participant's physiological performance is recorded and can be reviewed later; and didactic, where additionally, the participant's physiological performance affects game difficulty and is presented real time within the game.



In both the diagnostic and the didactic mode, the objective of the Auction Game is to develop investors' emotion regulation skills. By showing the level of arousal, the player gains an awareness of her emotional state and the effect emotion regulation has on decision making. Additionally, in didactic mode, the arousal level will affect the game play, similar to the Space Investor game. To be able to play successfully the participant has to regulate her arousal. Participants obtain feedback on their behavioural and physiological responses to losses and missed gains. This provides important process feedback and helps elucidate the mechanisms that are responsible for the disposition effect. The Auction Game provides participants with an environment in which management of arousal levels can be practiced and rewarded; help them become more aware of their own physiological state through improved interoception; and provide a context for the practice and consolidation of emotion regulation techniques such as mindfulness.



Figure 5-3 View of the Auction game in didactic mode

The Auction game records physiological data from the participant via the xDelia psychophysiological framework, using an ECG sensor and the xAffect software. In diagnostic mode, physiological data is collected and can be analysed at a later stage, but it does not otherwise affect the game play. In didactic mode, the participant's arousal level is shown during game play and directly affects the difficulty of the game.

### **AUCTION GAME (DIDACTIC MODE)**

In didactic mode, the Auction Game aims to raise awareness in participants about their internal physiological state and to train emotion regulation. We use constantly measured heart rate as a proxy for arousal. To increase participants' awareness of their physiological state, the current level of arousal is shown in real time during game play by an arousal meter (Figure 5-3). To train emotion regulation, the level of arousal directly affects game difficulty. Price estimations shown on the screen are directly linked to participant's emotional arousal level. The participant is required by up- or down-regulating to keep their arousal within specified bounds indicated by the on-screen dial.

The further a participant's arousal level is away from the prescribed bounds, the more the price estimates deviate from the true price, while staying within the bounds causes stock price estimations to approach the true price. Hence, in the didactic mode of the game, a participant's ability to earn money is strongly related to her skill to regulate emotional arousal state.

### **AUCTION GAME (DIAGNOSTIC MODE)**

In diagnostic mode, the Auction Game identifies the participant's emotional profile by measuring her physiological reactions to the experience of a loss, a forgone gain, or a gain. Shefrin and Statman (1985) postulate that "aversion to regret provides an important reason why investors may have difficulty realizing gains as well as losses." The participant wears an ECG sensor and her physiological reactions are recorded for later analysis.

In this version of the game, the participant plays ten rounds of five trading decisions, each time choosing whether to buy, sell, or not to trade. By trading he or she can experience gains and losses. After each decision, but also after each level (= five trading decisions) the participant is presented with feedback on her performance. This feedback is designed to trigger emotional responses such as frustration (of taking an incorrect decision – and hence losing money), joy (of taking the correct decision – and hence winning money) or regret (of how much money could have been earned). For the "regret information", the participant experiences through this feedback how much they could have earned if they had made 5 correct decisions. Other informational events intend to reveal for instance joy or frustration.

The diagnostic mode allows us to measure the average physiological reactions to the participants' experience during game play and compare these with the game performance or the performance on other tasks. Trainers for instance can identify the emotional imbalance that participants show on an individual basis, and whether this imbalance is reflected in their exposure to the disposition effect. With this approach, we can also measure how emotion regulation interventions show up in participants' physiological responses over time.

**Where evaluated:** S-M4, S-M5, S-M6, S-M8, S-HPa. Further details can be found in D9-2.3.3, and D20-6.3.3.

**Where used:** Diagnosis and feedback, Skill development



## Two Index Game

The Two Index Game is a fast paced serious game which challenges a single player to buy and sell assets in a set number of timed levels and perform as close as possible to playing perfectly relative to a benchmark. The game emulates decision making processes within investment and trading, in a non-specific manner, and can perform diagnostics about exhibited cognitive biases, as well as incorporate feedback derived from these into game play in real-time.

The game is available in both diagnostic and didactic modes, enabling trainers to either use the game to diagnose the extent to which a participant may be subject to the disposition effect, or in didactic mode, where the game provides visual feedback to the participant and enables them to use it as a training tool to reduce the extent to which they are affected by this bias. In both versions the participant's tendency to this bias affects the continuing game play, and data is collected that can be later analysed by the trainers to understand the extent to which the participants displayed the disposition effect during game play.

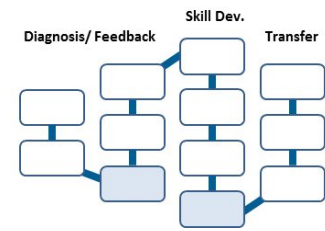


Figure 5-2: Two Index game (online version in didactic mode, dial giving live feedback on disposition effect)

The objective of the game is to make participants aware of the disposition effect and to train them to regulate such biases. The game was designed for a relatively high level of ecological validity for individuals who may be or potentially will be involved in financial decision making under high levels of uncertainty. Of particular importance, however, is to create a set of decision making tasks that do not elicit in the player an inappropriate reliance upon real-life practices, which may interfere with the learning objectives of the game and may give rise to complex emotional responses and decision making behaviours that confound analysis and feedback.

When playing the game, the participant is presented with two indices: the Value Index, showing current asset prices, and the Predictor Index, which partially determine the tradable stock value. The player's task is to buy and sell the assets using these indices at the best moment to maximise profit and perform as close as possible to

a benchmark: their performance is presented as a percentage distance from optimum, changing during game play. The participant is taught the game through an initial tutorial which walks them through the game demonstrating key features, and gives them the opportunity to practice before the real game starts. The game is structured so as the levels progress more options are made available, allowing for more possibilities for taking risk and ways of transacting. To begin with the player can only buy single assets, then they are able to buy multiple assets at a time, and finally they can short sell.

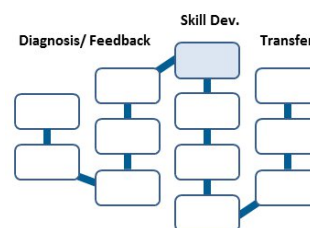
The game is available as an online version, or can be installed as a standalone local version for computers that are not connected to the internet. Both versions offer the same functionality.

**Where evaluated:** TIG-1, S-M1, S-M2, S-M5, S-M6, S-M7, S-M8. Further details can be found in D9-2.3.3 and D20-6.3.3.

**Where used:** Diagnosis and feedback, Skill development

## Mindfulness training

Mindfulness is associated with general improvements in well-being, emotion regulation and coping with stress. Mindfulness techniques are commonly used to bring about lasting change in individual levels of awareness, acceptance, attention, and emotion regulation. Mindfulness training has proven effects in health psychology with respect to emotion regulation in the context of dealing with stress, anxiety and depression (e.g. Segal, Williams, & Teasdale, 2002). Additionally, mindfulness training is associated with changes in brain activity in areas involved in decision-making (Hölzel et al., 2011; Kilpatrick et al., 2011)



### xDELIA MINDFUL TRADING TRAINING

Studies that we carried out earlier in the project showed that even short mindfulness exercises were quite effective as a strategy for training emotion regulation skills. Based on these findings and on acceptability studies with investors, we developed the xDelia Mindful Trading Training, a mindfulness training programme for financial decision making tailored to the specific needs of private investors. The training course teaches basic elements in mindfulness that are particularly relevant to investors and offers a structured approach to learning emotion regulation during trading. Compared to more traditional mindfulness interventions, our training approach has a stronger focus on increasing levels of attention, emotion regulation, and interoception skills. Moreover, our course is online and completely self-guided, and, with only four weeks, shorter than the more common 10-week format. Such a format better fits the needs of private investors who may find regular face-to-face courses too time-consuming, though an expert can be contacted through the main menu via email. In each week, training addresses one major theme:

**Week 1:** Attention and awareness to automatic pilot behaviours and emotions

**Week 2:** Attention to breathing and staying in the present moment

**Week 3:** Attention to thoughts and allowing thoughts and emotions

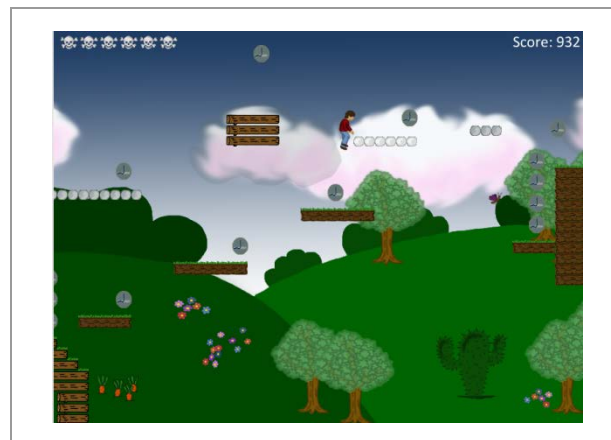
**Week 4:** Attention to dealing with emotions during future trading following the Mindful Trading Training.

The exercises in each week address a specific topic relevant to private investors and tap into various aspects of mindfulness, and the package contains long and short meditation forms, emotion regulation exercises, and exercises in attention and awareness. Using a personalised login and password, participants who enrol in this training course log in to a website hosted by Saxo Bank where over a four week period they gradually complete a series of exercises.

To support the course, two interactive tools have been developed: xMedit-Mate, a mindfulness training tool; and xHale Athlete, a computer game that enables the participants to practice mindfulness skills.

### **MINDFULNESS GAME: XHALE ATHLETE**

The xHale Athlete game is an introduction to mindfulness and can be played anytime, before and after the training. It is designed to immerse participants playfully in mindfulness techniques, and to motivate them to learn more about mindfulness and enroll in the xDelia Mindful Trading Training. The game takes the form of a fast paced and effortful platform game and allows the participant to engage in a specific mindfulness exercise and explore how this affects game performance.



*Figure 5-3: The main character jumps from platform to platform in the xHale Athlete game*

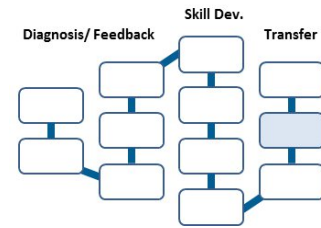
### **MINDFULNESS APP: XMEDIT-MATE**

The xMedit-Mate is an online application that integrates various tools to help participants practice mindfulness techniques. The tool is used in the xDelia Mindful Trading Training course to train specific emotion regulation skills via mindfulness. One powerful technique in mindfulness training for instance is the ability to recognise emotions at an early stage and to use breathing as an anchor, to return to in more stressful periods. This requires practice and xMedit-Mate is designed as a tool to facilitate the training of such mindfulness skills.

xMedit-Mate consist of six parts: a planner to schedule and organise the meditation sessions; a mindfulness bell that rings either randomly or at specified times to signal time for conducting breathing exercises and other meditation exercises; a meditation timer to set the duration of a meditation exercise; a paced breathing application where participants are instructed to perform an inhaling and exhaling breathing exercise at a selected pace; a questionnaire to evaluate the effectiveness of the training exercises in terms of perceived increases in mindfulness and to record the progress of participants' state mindfulness over time; and a tool to give feedback to participants about a variety of aspects of their training and their progress over time.

## Peer forum

Working with private investors to understand the requirements and features of tools and techniques that support their learning and skills development has been central to xDelia. Through interviews and informal discussions with investors, and through monitoring popular online forums such as the Trader Risk and Psychology group on LinkedIn, it became clear that peer discussions and exchange of ideas are highly valued by investors. As a result, future developments of the xDelia Learning Pathway will include the use of peer forums that enable participants to share their learning experiences.



We have identified a set of characteristics that investors are looking out for most in such communities, and have designed a peer forum for xDelia along those lines. The process for developing such tools are well understood and evidence on the pedagogical benefits and means of supporting learning through such spaces has been widely researched (Jaques & Salmon, 2007; Salmon, 2000). Although our project has not implemented a 'physical' demonstrator of the peer forum, we have developed a simple proof of concept that incorporates the key elements into an online community and that can be implemented into Saxo Bank's product and service portfolio.

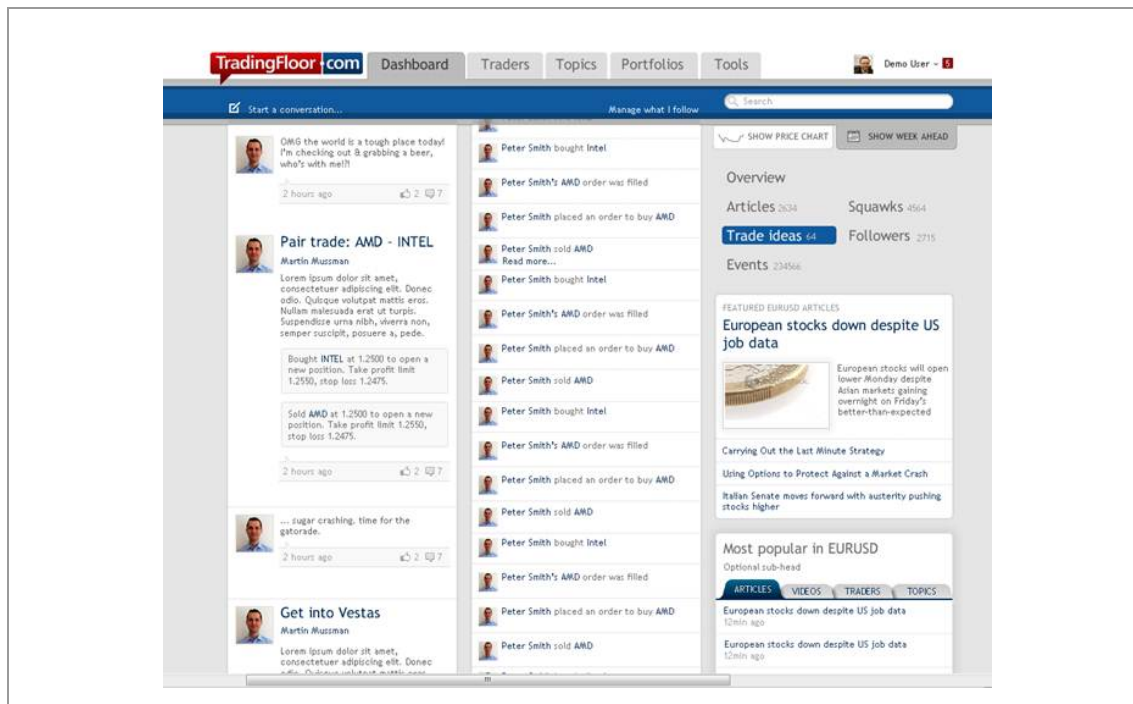


Figure 5-6: Prototype xDelia social media space

We anticipate that the xDelia Learning Pathway will include a social media space that allows participants to post entries that are either private and displayed for instance as a personal diary, or public where they are posted to special interest groups of the forum "wall". In this manner we provide the tools that enable private reflection, shared reflection amongst participants on a single cohort of the learning pathway, and also wider knowledge exchange, for example between past and present xDelia Learning Pathway participants.

**Where evaluated:** designed but not evaluated during the xDelia Project

**Where used:** Transfer

## Diary and reflective practice tools

Our work on domain specific approaches to emotion regulation (Vohra & Fenton-O'Creevy, 2011) together with other engagements with stakeholders highlighted the important role of 'writing things down' as a commitment mechanism, a support for emotion regulation, and as a medium for critical reflection. As a result, we decided to develop a trading diary approach to facilitate reflection and to provide an effective transfer channel to trading practice..

A paper and pen prototype of the diary tool was developed and trialled for a period of three weeks, to evaluate its effectiveness for transfer of learning, for effective regulation of emotions, and as a tool to help mitigate the impact of emotions on trading. Further, this prototype enabled the testing of the following key features of the actual online diary: reflection on trading practice via time stamped entries; recording of emotional state before, during and after trading; and recording compliance of and reflection upon mindfulness training and its effect on trading practice.

Similar to the peer forum, we anticipate that the diary will be part of a broader social media space provided by Saxo Bank as part of their product and service portfolio, and that it will integrate seamlessly with other elements, such as the peer forum and the diagnostic learning elements, and that it will provide a structured template method for private investors, to help them capture their emotional states as well as reflect on trading performance. Screen capture of the state of the market at the point of diary entry will be supported, and psychophysiological data may be captured via the xAffect framework to understand emotion regulation performance at the time.

**Where evaluated:** S-M9, S-M10. Further details can be found in D9-2.3.3, and D20-6.3.3.

**Where used:** Transfer

## Web interface

The primary point of access for the xDelia Learning Pathway is via an overarching web interface. This enables learners to access the site both at training locations and remotely between face to face training sessions, and provides an encompassing structural framework.

The majority of learning elements are implemented through this interface and in some cases share resources and data. Learning elements accessed via the web interface include online diagnosis, multimedia personalised feedback, supporting pedagogy in various media, serious games (the Two Index Game, xHale Athlete and xMedit-Mate), mindfulness training and a peer forum. A web version of a reflective diary is planned to be incorporated in the near future, and future versions of this diary will be able to be synchronised with psychophysiological data collected via the xAffect sensor toolkit.

Where activities are not web-based, such as the Auction and Space Investor games, strong support of those activities is integrated into this online interface.

**Where evaluated:** S-M1, S-M2, S-M8d, S-M10. Further details can be found in D9-2.3.3, and D20-6.3.3.

**Where used:** Diagnosis and feedback, Skill development, Transfer

## EVIDENCE-BASED DESIGN AND EVALUATION

Around 35 studies in which a total of 1422 students and 793<sup>6</sup> traders and private investors participated have served the design and evaluation of the learning elements and key segments of the xDelia learning pathway. In addition, we ran a few larger studies such as the disposition effect study (IFS-3) with 3,000 investors, the Dutch Household Panel Survey on financial capability and emotion regulation with a population of approx. 5,500 subjects, and study on financial capability, emotion regulation and impulse buying as part of the BBC LabUK 'Big Money Test', with over 100,000 participants. The latter two were studies of the financial capability stream of the xDelia project, which is not discussed in this report.

The studies can be categorised either as lab-based studies (to test for instance a concept, hypothesis or game in a controlled setting using participants who are not necessarily members of the target group), field studies (designed to validate the findings from the lab-studies in a more realistic setting and with investors), or evaluation studies (mainly user experience studies built around other lab or field studies and conducted in parallel). In the following sections, we describe the various studies and briefly discuss the results.

### Foundational and design studies

Although existing research in emotion regulation and decision making provided us with some strong evidence in support of our approach, there were still gaps that needed to be filled in if we wanted to target specific decision biases in financial trading and investment. Moreover, the novelty of learning interventions that make use of this research posed some important challenges for designing an appropriate pedagogical approach and technologies that are able to support such a new approach. Hence, in the early stages of the project, we conducted a series of foundational and design studies to improve our understanding of emotion regulation in trading and to explore key features of the learning design. Taken together, the foundational and design studies:

- provide support for our approach to focusing on emotion regulation learning interventions as an important route to improving financial decision-making
- provide a good basis for interpretation and feedback of physiological data captured during live trading activity and trading games
- suggest the disposition effect to be an economically important and viable candidate for intervention
- point to the importance of domain specific strategies for emotion regulation in trading alongside more generic approaches
- suggest mindfulness approaches for improving emotion regulation to be worth further investigation and evaluation
- provide important input to learning design
- show investors to be receptive to our games based and emotion regulation based approach and the xDelia developed games to show some promise in early evaluations.

The following table briefly describes the foundational and design studies. Sections 6.1.1-6.1.8 below summarise the findings.

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<sup>6</sup> This includes participants from foundational, learning effects, and user experience studies

## FOUNDATIONAL AND DESIGN STUDIES

TFS1	<b>Trader field study 1</b> <i>Exploratory study with traders in an investment bank</i>
	<b>Aim:</b> To a) establish the viability of our planned measures in the field setting; b) provide a working definition of 'performance episode' for the next stage of research; c) provide a rich description of the interplay of trader behaviour, emotion arousal and emotion regulation across a performance episode; and d) examine qualitative differences in emotion and emotion regulation responses between less experienced and expert traders during live trading.
	<b>Findings:</b> Despite some problems with noisy data the sensor technology operated well in this setting and was clearly viable for measurement purposes and acceptable to study participants. Think aloud data showed novices to be very preoccupied with the detail of trading and suffering significant cognitive overload while the expert trader was concerned mostly with a strategic overview of market conditions. We found major differences between physiological reactions of the novices and more experienced traders to market events. We established the importance of scheduled news releases as providing easily identifiable market events when physiological reactions to market events can be examined at a fixed point in time and over a predictable timescale. This is important both for further research but also for the design of feedback mechanisms. We established expectations for later studies and development of feedback mechanisms about the timescales over which cardio-responses to market events unfold. Combined with the exploratory interviews this study pointed both to the importance of domain specific approaches to emotion regulation whilst trading and the role of anticipatory arousal in preparing for scheduled market news events.
TFS2	<b>Trader field study 2</b> <i>Emotion regulation and performance – an inter- and intra-trader study</i>
	<b>Aim:</b> The study examines the relationship between emotion regulation and performance both at the individual level and at the level of performance episodes. The study will have two components, a between trader comparison in which the individual trader is the unit of analysis and a within trader comparison in which performance episodes clustered within traders are the unit of analysis. The study provides an empirical basis for understanding the relationship between trader expertise, susceptibility to biases and emotion regulation. It also provides a professional benchmark group for comparison with the (larger investor sample)
	<b>Findings:</b> Our hypothesis for a relationship between trader expertise and emotion regulation is supported by our finding of a positive association between trading experience and mean high frequency HRV whilst trading. We also find differences in patterns of arousal between novices and more experienced traders. In particular, inexperienced traders typically show much more marked anticipatory arousal in the half hour prior to a scheduled news event and a pronounced peak of arousal at the news event (as measured by heart rate). In contrast very experienced traders show a much more modest and gradual increase in arousal across the period of the news event. A more qualitative examination of HRV patterns across the trading day and around news events suggests a key difference between low and high experience traders is in the period for which peaks of HF HRV are maintained. For experienced traders significant peaks in HRV show a slow decline and are maintained over significant periods. Inexperienced traders in contrast tend to show more rapid decline from peaks of HRV associated with news events.
IS1	<b>Short mindfulness induction study (student population)</b> <i>Inducing mindfulness and the effect on BART risk taking</i>
	<b>Aim:</b> To investigate feasibility of mindfulness as a candidate for our learning intervention, this study examined whether short mindfulness inductions could be effective in inducing a mindful state in a (sceptical) student population.
	<b>Findings:</b> The mindfulness groups showed higher levels of state mindfulness and awareness to bodily signals during



	<p>the experiment. There were no differences between the three mindfulness exercises in terms of effectiveness. Additionally, the groups did not differ with respect to trait mindfulness or dispositional emotion regulation, so the effects were short-lived, as expected. Students were not sceptical or negative about the mindfulness inductions. No differences were observed between groups on the BART task. One explanation for this lack of effect on risk taking may be that the BART task was at the end of the study (which lasted about an hour), and effects of a short interventions may have worn off at that time. We conclude that mindfulness inductions can be effectively applied in our student population. Another implication is that a more sensitive risk taking task is required in order to find effects of short mindfulness inductions and that risk taking tasks should be scheduled close to the mindfulness induction.</p>
IS2.2	<p><b>Short mindfulness induction study (investor population)</b> <i>Inducing mindfulness and the effect on CCT risk taking</i></p>
	<p><b>Aim:</b> In study IS1, we showed that mindfulness induction can be effective in student samples. IS2.2 explores these effects in a private investors population. What we try to establish in this study is whether a short mindfulness induction affects financial risk-taking on a stressful version of the Columbia Card Task; and how performance in the Columbia Card Task relates to self-reported real-world performance?</p>
	<p><b>Findings:</b> Decision-making on the Columbia Card Task was associated with real-world investment performance. The better the investment performance in the past 12 months, the more normative decision-making was demonstrated on the Columbia Card Task. Moreover, changes in testosterone and cortisol levels were related to performance. Specifically, rises in testosterone levels during the task were related to worse financial performance. No differences were observed between the mindful and non-mindful participants. There were several situational artefacts that may explain this latter finding. Participants found the tasks highly engaging and expressed considerable interest in game-based learning approaches for investors. The implications of this study are that the Columbia Card task proves an externally valid task for future xDelia lab studies and that mindfulness bears further investigation as a viable intervention in private investors.</p>
IS3	<p><b>Exploratory emotion regulation intervention study (investor population)</b> <i>Study to explore the link between emotion regulation instructions and game performance.</i></p>
	<p><b>Aim:</b> This study investigated whether participants who receive explicit emotion regulation instructions can effectively manage arousal levels and thereby perform better in the Aiming Game, the precursor of the space investor game. A combination of EMG/EEG (the EPOC headset) was used to measure participants' arousal whilst playing the game.</p>
	<p><b>Findings:</b> Emotion regulators were not more effective in shooting the targets than non-regulators. However, emotion regulators did report lower subjective arousal levels, but not on objective arousal measurements (EPOC). We speculate that since the EPOC may not have adequately detected differences in arousal levels, both groups received similar distortions throughout the game. The main implication is that the aiming game and the sensor to measure arousal require further calibration in terms of sensitivity. This study provided a first test of this game with an investor population but prior to the availability of a reliable commercial sensor package (the movisens ekgMove device) and a robust interface for measuring real time arousal.</p>
RS1	<p><b>Regret feedback study I (student population)</b> <i>How do regret-related feedback and regulatory style affect performance in an auction task?</i></p>
	<p><b>Aim:</b> This study analyses the effect of regret related feedback information on decision making in an auction tasks on a student population. Three key questions were addressed: (1) Does regret related feedback information induce the emotion regret? (2) Does the induction of regret influence decision making in an auction task? (3) Is there a difference in efficiency and outcomes between different emotion regulation strategies?</p>

	<p><b>Findings:</b> Regret feedback information provokes high levels of regret in participants. This reveals participant self-perception as well as bidders' high physiological responses to the information. Moreover, regret has a significant influence towards participants' behaviour in the task. Regret from feedback after losing an auction task leads to significantly worse decisions compared to regret from winning an auction task too high. Physiological data reveals a strong asymmetry between regret from winning at an unfavourable price compared to losing when it might have been possible to win. This is a potential explanation for several biases in financial decision making such the disposition effect. 36% of the subjects used suppression strategies for emotion regulation and came to significantly more aggressive bids and hence worse decisions compared to the rest of the population. This is not the case for subjects using reappraisal strategies, who seemed to be able to more quickly down-regulate negative high emotionality after negative feedback information. An overestimation of regret after losing leads to worse financial decision making compared to adequate processing of regret.</p>
RS2	<p><b>Regret feedback study II (student population)</b>  <i>How do regret-related feedback, regulatory style, and uncertainty affect performance in an auction task?</i></p>
	<p><b>Aim:</b> This study observed economic behaviour and physiological data (heart rate, heart rate variability and skin conductance) in a regret task with varying levels of uncertainty. The two main questions in this study were: (1) Does the strong influence of regret feedback persists under more realistic assumptions with increasing levels of uncertainty? Does regret increase with level of uncertainty? (2) Are suppressors more exposed to the effects of uncertainty compared to reappraisers? Does the difference in financial performance between varying emotion regulation strategies persist in a more realistic setting?</p>
	<p><b>Findings:</b> Results reveal that information feedback that induces regret also remains an important influencing factor towards bidding behaviour when uncertainty increases. Also uncertainty has a strong influence on participants' decisions. Higher levels of uncertainty increase risky behaviour and hence increase subjects' experienced regret. However, regret is only experienced when winning at a favourable price would have been possible. In this study there are no significant differences in financial performance between subjects using reappraisal and suppression strategies. This might be due to the small number in the suppressor group (27%).</p>
MF1	<p><b>Mindfulness and financial decisions study I (student population)</b>  <i>Does mindfulness affect financial decision performance?</i></p>
	<p><b>Aim:</b> This study investigates whether short mindfulness interventions improve financial decision-making within a student sample. It is similar to IS2.2, except that it uses a student and is conducted in a laboratory. This is the first study to investigate the effects of mindfulness on financial decision-making performance to determine whether mindfulness is a good candidate for the learning intervention.</p>
	<p><b>Findings:</b> Replicating the findings from our earlier work, the mindfulness groups demonstrated higher levels of state mindfulness and awareness to bodily signals during the experiment. In addition, this study showed borderline significant positive effects of mindfulness on performance in an attention task (STROOP task). Finally, on the Columbia Card Task, both groups performed equally well in terms of financial performance. However, the mindfulness group did process more information before making financial decisions. One implication of the study is that the decision making task should be more stressful in order to become more sensitive to mindfulness inductions.</p>
MF2	<p><b>Mindfulness and financial decisions study II (student population)</b>  <i>Does mindfulness affect financial decision performance under stress?</i></p>
	<p><b>Aim:</b> This follow-up study to MF1 investigates whether a short mindfulness intervention improves financial decision-making under stress. This study adds a bonus payment and a stressor to the MF1 setup. Students could earn a significant bonus on top of the standard fee for participation. We also added an experimental manipulation of psychological stress in form of time pressure to the decision-making task since previous research suggests that</p>

	<p>mindfulness is particularly beneficial in managing stress.</p> <p><b>Findings:</b> Participants in the mindfulness condition demonstrated higher levels of state mindfulness, but not in trait mindfulness. Those who practised mindfulness took loss information significantly stronger into account when making a decision. Thus, mindfulness helped participants pay more attention to loss information. Only in individuals high in trait neuroticism were the differences between the mindfulness and the control group statistically significant, indicating that mindfulness training only helped people with high levels of neuroticism.</p>
IFS3	<p><b>Measuring the disposition effect (investor population)</b> <i>Exploratory study around the disposition effect</i></p> <p><b>Aim:</b> This study examined four questions: Does the disposition effect reduce investor performance? How might the disposition effect be effectively measured in trading data for large numbers of trades in ways that are meaningful at the level of the individual investor? What can be said about the mathematical form of biases manifest in data which relate to the disposition effect? Does the disposition effect manifest itself differently in professional traders than in the target cohort (investors)? These questions were addressed through theoretical analysis, simulation, and an empirical test on the trading data of over 3000 investors.</p> <p><b>Findings:</b> A novel algorithm and data processing approach was developed for measuring disposition effect in high frequency trading data and during gameplay, based on more precise computations of temporal effects in decision-making. Disposition effect is associated with reduced investor financial performance both in simulation and in empirical tests, which bear out what may be already demonstrated in mathematical analysis. Mathematical form (power law behaviour) of temporal bias in decision-making under disposition discovered. Professional traders show markedly lower disposition effect than private investors. Trading frequency was shown to be related to the level of disposition effect among private investors.</p>
IS5	<p><b>Arousal induction study</b> <i>Are pictures and music effective in inducing arousal in an auction game?</i></p> <p><b>Aim:</b> This study evaluates whether pictures and music are effective as distracters during decision making tasks in an auction game, and to determine the influence of <i>positive and highly arousing affect</i> on the decision making processes. The two main questions were: Are music and IAPS pictures a good stimuli to induce levels of high arousal in auction games? Are reappraisers better in regulating their levels of emotional arousal compared to suppressors and do they arrive at better financial decisions?</p> <p><b>Findings:</b> Pictures and music are useful stimuli to induce high levels of arousal. Participants in the arousal treatments reported strong levels of valence and arousal measured with the affect grid (Russel 1989). This is supported by participants' high levels of skin conductance in the arousal treatments. Moreover, participants in the highly arousing treatment take significantly more risky decisions compared to the control group. Suppressors come to significantly worse decisions compared to non-suppressors (measured via ERQ). Suppressors place significantly more aggressive bids and hence come to worse financial decisions and hence economic payoffs. Subjects identified as suppressors place significantly more aggressive bids and their financial performance is worse compared to subject using reappraisal strategies or to subjects that could not be classified.</p>

## LINKS BETWEEN EMOTION REGULATION AND PERFORMANCE ON FINANCIAL DECISION-MAKING TASKS

Taken together, the results from Year 1 exploratory studies, the regret studies and the trader field studies (RS1, RS2, TFS1 and TFS2) provide significant support for our approach to focusing on emotion regulation as an important route for improving financial decision-making.

Our experimental laboratory studies show a significant relationship between emotion regulation strategy and financial behaviour and outcomes. In particular, subjects using suppression strategies come to significantly worse decisions compared to benchmark. We also find, as in previous studies that regret associated with missed gains affects behaviour less strongly than regret associated with losses, an important explanation for the disposition effect (Fogel & Berry, 2006). However, we are also able to show that this asymmetry between behavioural responses to losses and missed gains is accompanied by an asymmetry in physiological response and that the size of physiological response and behavioural response is moderated by emotion regulation strategy. These results have fed into the design of the Auction Game. The didactic mode of the Auction Game especially addresses this asymmetry. Players get feedback about their behavioural and physiological responses to losses and missed gains. This provides important process feedback to aid understanding of the reactions which underpin the disposition effect.

We also find in our trader field studies that emotion regulation effectiveness whilst trading (as measured by high frequency heart rate variability whilst trading; HF-HRV) rises with expertise (Fenton-O'Creevy, Davies, Lins, Richards, & Vohra, 2012) and declines in market conditions with high volatility (as measured by the VIX<sup>7</sup> 'fear factor'). This is an especially strong finding given the known decline in high frequency heart rate variability with age. Indeed we see a decline in resting HRV with trader experience, consistent with this age decline effect. This finding coincides with the evidence from our interviews with traders and investors that managing emotional reactions to market events and trading outcomes is important if they are to avoid bias, and that this is a skill which they develop over time (Vohra & Fenton-O'Creevy, 2011). This also coincides with the findings of a prior qualitative study (Fenton-O'Creevy, Soane, Nicholson, & Willman, 2011) that expert traders have more effective emotion regulation skills than novices and moderate performers. These HRV findings are particularly interesting in understanding adaptive behaviour since HF-HRV is an effective indicator of moment by moment adaptation to the environment. HF-HRV indexes the activity of the parasympathetic nervous system. Whilst the sympathetic nervous system is responsible for activating responses to threat and opportunity, it is the activity of the parasympathetic system which sculpts responses to provide an adaptive response to the environment.

These studies also provided a more nuanced understanding of patterns of physiological response to information and trading outcomes. This is of direct use in the design of our learning games and approaches to delivering feedback.

## RESULTS ON THE DISPOSITION EFFECT

The disposition effect is the tendency to hold assets which would sell at a loss for longer than assets which would sell at a gain. In colloquial terms an investor who suffers from the disposition effect cuts their wins and runs their losses. This bias arises out of the desire to avoid the emotional pain of realising a loss (Frydman, Barberis, Camerer, Bossaerts, & Range, 2011). So long as the investor does not convert a paper loss into a realised loss they can console themselves that 'it will probably increase in value again'.

Existing approaches to characterising the disposition effect are primarily designed to demonstrate the existence of the effect in a given population rather than diagnose the extent to which individuals display this bias (Barber, Yi-Tsung, Yu-Jane, & Odean, 2007; Feng & Seasholes, 2005; Feng & Seasholes, 2008; Odean, 1998). Such

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<sup>7</sup> The VIX is the Chicago Board Options Exchange Market Volatility Index, also known informally by traders as the 'fear index'. It measures market expectations about future price uncertainty

approaches have also typically been constrained by only having trading data available on a daily basis. With access to moment by moment trading data – as for Saxo Bank clients and in a trading game – other approaches become possible. However, given the consequent volume of data, analysis presents data processing challenges.

We have developed a novel, theoretically driven approach to measuring the disposition effect and approaches to real time calculation of disposition effect in a game environment<sup>8</sup> and an approach to calculating this measure for individual investors' trading histories (Yee & Lins, 2011a). A novel element of this approach involves using a market information based measure of time<sup>9</sup> rather than chronological time in the calculation of asset holding times.

A simulation study and an empirical study (IFS3) based on trading data from Saxo Clients and professional traders showed, first, that susceptibility to the disposition effect is associated with poorer financial performance and, second, that professional traders show markedly lower levels of disposition effect in their trading than private investors (Yee & Lins, 2011b).

This provides support for our view that a) the disposition effect has economically important effects on financial decision-making and b) that the disposition effect is potentially amenable to intervention since professional traders show reduced susceptibility.

This work has also provided an important foundation for the design of the Two Index Game. The Two Index Game is a game based on a simple trading task, which like most financial markets, elicits a disposition effect in the majority of players.

## **MINDFULNESS APPROACHES**

In developing approaches to helping investors improve their ability to regulate their emotions more effectively, we are investigating the efficacy of mindfulness approaches (Davidson et al., 2003; Kabat-Zinn et al., 1992) in the context of emotion regulation. Mindfulness approaches use meditation based techniques to enable practitioners to develop the capacity to notice unhelpful thoughts and feelings, and allow them to pass without being drawn into acting on them or continuing with them. We have been building here on established practice in a domain where there is significant evidence of success in enabling individuals to learn more effective emotion regulation strategies – cognitive behavioural therapy (CBT). The most recent approaches to CBT draw on the Buddhist tradition of mindfulness (Baer, 2003; Kabat-Zinn, 2003) and have had considerable success in using mindfulness training as a foundation for more effective regulation of emotions and behaviour (Davidson et al., 2003; Kabat-Zinn et al., 1992). Our innovation here is to translate key elements of these approaches into the domain of financial decision-making and develop approaches to online delivery of mindfulness training that can be delivered via a learning space attached to a trading platform.

Our year 2 studies of mindfulness focused on two primary questions. First, can mindfulness interventions induce a mindful state and an improved emotion regulation in the context of a financial decision-making task? Second, can mindfulness inductions improve performance in a financial decision-making context? These studies show

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<sup>8</sup> The Two Index Game (see below)

<sup>9</sup> In simple terms: this measure of time passes slower than clock time when there is little market activity and faster than clock time when there is high market activity

that even brief interventions can successfully induce a mindful state, improve attention, increase capacity to monitor financial information, and improve financial decision-making.

### **DOMAIN SPECIFIC APPROACHES TO EMOTION REGULATION IN A TRADING CONTEXT**

We analysed data from early trader and investor interviews alongside data collected in TFS1 and data from a prior study (Fenton-O'Creevy et al., 2011 ). The purpose of this analysis was to examine approaches expert professional traders use in regulating their emotions whilst trading, as a benchmark for private investor behaviour.

While it is clear that much of this emotion regulation fits generic strategies described by Gross and colleagues (Gross & Thompson, 2007), traders also deploy emotion regulation approaches which are specific to the trading domain. In particular, many traders follow a discipline of explicitly writing down trading strategies and of writing down reasons for changing strategy if they decide to make changes. This serves first as a commitment mechanism. It becomes harder to persuade yourself that you didn't really intend the original strategy. It also serves as a trigger for self-monitoring, and it provides opportunity for an intentional cognitive approach to emotion regulation (Vohra & Fenton-O'Creevy, 2011).

This analysis provides a basis for our work to design an online diary tool and reflective practice templates.

### **THE SPACE INVESTOR GAME**

The Space Investor Game – previously the Aiming Game – was designed and prototyped to support learning of emotion regulation that uses real time data from a physiological measure of arousal. Since management of physiological arousal and awareness of physiological state is closely related to effective emotion regulation, the hypothesis was that repeated game play would support development of emotion regulation skills.

Study IS3 conducted an early evaluation of the game with a group of investors. Interviews with participants showed them to be enthusiastic about engaging with this kind of game and very interested in approaches to improving emotion regulation whilst trading. However, in this initial evaluation with an early prototype, we found no relationship between game performance and emotion regulation strategy. Because this was an early trial, we were unable to deploy our preferred sensor solution, which at that point had not yet been fully developed, and instead were relying on a prototype EPOC EEG/EMG headset for measurement of arousal.

Based on these and other trials the game was redesigned and developed into a new game (Space Investor) which retained the basic link between physiological signals and gameplay, but introduced a stronger game narrative and more sophisticated gameplay, but most importantly, featured the preferred sensor solution. Thus, year 3 trials of the game (SM-6, SM-7) consistently used Space Investor with the more sensitive and better calibrated sensor solution to measure heart rate.

### **THE AUCTION GAME**

The didactic version of the Auction Game uses physiological parameters to provide the players with a continuous feedback on their current level of arousal. The game was designed to help decision-makers improve two major aspects of emotion regulation. First, the game shall help players to improve interoception, that is, the conscious awareness of one's own emotional processes including single emotions and the overall emotional state. Second by rewarding good emotion regulation and punishing poor emotion regulation, the game actively

supports players in practicing emotion regulation strategies. To achieve these goals, the game features a challenging decision-making environment and elicits high levels of physiological arousal.

The diagnostic version of the game allows an evaluation of participants' performance and the corresponding physiological responses, measured as deceleratory heart rate response, to gains, foregone gains, and losses. This allows us to identify physiological traits that are affected by a participant's susceptibility to decision biases such as the disposition effect.

The arousal induction study (IS5) directly helped to design the Auction Game. The game was also pretested heuristically and for usability with students at BTH. This game is a direct development out of the work done in the year 2 regret studies (RS1 and RS2) and has been evaluated and further developed in year 3 studies.

### **THE TWO INDEX GAME**

The Two Index Game engages players in a trading game which abstracts key elements of the trading task. One index provides information that predicts with both lag and error the price of a second index. Participants have the opportunity to buy and sell (and later short sell) units of the second index. The game includes an artificial intelligence (AI) module which plays the game in parallel using only information available to the player and making optimal use of that information. The participant's score is calculated as a percentage of the optimal score achieved by the AI. The game also calculates the level of disposition effect shown by the participant in real time. This can be either fed back at the end of the game or displayed in real time.

The year 2 disposition effect study (IFS3) fed directly into the design of the Two Index Game. In year 2 the game was evaluated heuristically and for usability. Early results showed the game to elicit a disposition effect in the large majority of players and to produce a good distribution of disposition effect scores.

### **DIARY AND REFLECTIVE PRACTICE TOOLS**

Our work in year 2 on domain specific approaches to emotion regulation (Vohra & Fenton-O'Creevy, 2011) together with other engagements with stakeholders led to a better understanding of the role of 'writing things down' as a commitment mechanism, and a support for emotion regulation, as well as a support for critical reflection.

This led to our decision to develop a trading diary approach as a support for the transfer stage of our learning pathway. This also implied the need for further work in year 3 to develop our understanding of the optimal design for such a trading diary.

### **Evaluation of the learning elements**

Our approach to evaluation has been to evaluate individual elements of the learning pathway and, where possible, combinations of these elements. Because the full set of learning elements and the learning pathway only became available for trialling during the second half of the project, longitudinal evaluation of user experience and learning effects were beyond the scope of xDelia. We have carried out the evaluation at two main levels: evaluating effects of learning and evaluating user (private investor) perceptions of the learning experience.

**Data on user experience** during trials of learning elements was gathered through a combination of surveys, interviews, and focus groups with investors. We obtained data on:

- Usability
- User engagement and enjoyment
- User perceptions of learning outcomes and learning potential

**Data on effects** has been generated, where possible, via randomised control design studies. In particular we have examined the effect of learning elements on:

- Improved emotion regulation
- Improved mindfulness
- Improved interoception and body awareness
- Financial decision-making behaviour, including susceptibility to disposition effect

Taken together, our studies provide much support for the validity of the learning approach and the constituent learning elements:

- We have very positive feedback from investors suggesting that our learning approach is engaging, enjoyable, and a good basis for learning.
- There is good evidence for the effects of the learning interventions in achieving proximal goals of improving emotion regulation, mindfulness, and interoception.
- Our studies support the value of our sensor based games in diagnosing emotion regulation capabilities and the value of the Two Index Game in diagnosing a propensity to a disposition effect.
- We show a significant impact of training on disposition effect as measured in real world trading behaviour.

However, as is normal with such research we are also left with some puzzles which merit further research and in some cases suggest a need for further development of elements of our learning pathway.

- In some cases learning interventions lead to a paradoxical increase in disposition effect as measured by the Two Index Game. We have advanced some explanations for this finding but further research is needed to establish whether these are correct. This may involve gaining a better understanding of the ways in which playing behaviour evolves over time in repeated plays of the Two Index Game.
- Whilst we hypothesised the use of a reappraisal strategy to be associated with better performance in our emotion regulation games, in some cases better performance is also associated with use of a suppression strategy for emotion regulation. This is unexpected in the light of previous research on these emotion regulation strategies and merits further investigation.
- The diagnostic questionnaire scales have mixed success in predicting financial behaviour and further development is needed here.

## **USER PERCEPTIONS AND EXPERIENCE**

Feedback from participants on the learning value of our learning elements and their engagement with them was, overall, very positive, although often provided useful help in thinking about how to improve our approach.



The following table lists the studies that evaluated perceptions and user experience of investors. A brief discussion of some of the findings follows. See D20-6.3.3 for a full description of these studies and the methods we have used to collect the data.

EVALUATION STUDIES (USER EXPERIENCE)	
EV-1	<b>Investor interviews</b> <i>Conducted alongside multiple effects studies</i>
	A series of interviews conducted between November 2010 and May 2012 with investors who took part in our studies. Guided by the design and evaluation (D&E) framework, the aim of the interviews was to obtain stakeholder feedback on the xDelia games, and channel it into future development work. The interviews were also used to gather feedback on the stakeholder perspective of the xDelia approach.
EV-3	<b>User experience evaluation surveys</b> <i>Collated alongside multiple effects studies</i>
	These studies evaluated investor experience of learning elements for <b>skill development</b> . Evaluation surveys were administered to investors both at the single-day conference data collection events S-M8(a) & S-M8(b), at the end of study S-M1/2 and both at the start and end of the longitudinal study S-M8. These surveys were typically followed by an interview.
EV-4 EV-5	<b>Evaluation of feedback trials</b> <i>Conducted alongside multiple effects studies</i>
	These studies evaluated investor experience of learning elements for <b>diagnosis and feedback</b> . These include the diagnostic emotion regulation questionnaire and the personalised feedback on their habitual emotion regulation strategies; the automated calculation of their disposition effect based on past trading history and the personalised feedback on this; and the two index game as a diagnostic tool for the disposition effect. These evaluations were conducted during the S-M1/2 and the S-M8 studies. In addition, we conducted follow on telephone and email interviews.
EV-6	<b>Diary evaluation</b> <i>Conducted /collated from multiple interviews, surveys, and a workshop, alongside effect studies</i>
	These studies evaluated investor experience of learning elements for <b>learning transfer</b> . Several diary evaluation studies were conducted during S-M8 and S-M9. During S-M8 Camden Longitudinal study with private investors, a prototype mindfulness diary was trialled (S-M9). Feedback was collected on the usefulness through interviews, Final Stakeholder Workshop and the post-study user experience survey.
EV-7	<b>Evaluation of the overall learning intervention</b> <i>Conducted /collated from multiple interviews and a workshop alongside effect studies</i>

<p>Stakeholder perceptions of the usefulness of the approach have been collected as part of the evaluations of the separate elements. The early stakeholder interviews were conducted in 2010 and early 2011 as prototypes of the games and methods of collecting emotion arousal data were trialled with private investors. These studies and interviews took place at conferences aimed at both long term investors and private traders. As we moved into the longitudinal year 3 studies (S-M1/2 &amp; S-M8) with investors who specialised in trading rather than long term investing, we administered surveys to participants who took part in each study. An important mechanism for obtaining the stakeholder perspective on the year 3 achievements of the xDelia project has been the Final Stakeholder Workshop held in month 39.</p>
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### *Diagnosis and feedback*

The diagnosis and feedback stage of the learning pathway uses an online diagnostic questionnaire and delivers personalised (multi-media) feedback to participants on their emotion regulation strategies and the extent of disposition effect they show in their trading history, alongside didactic materials on emotion regulation and trading biases. They also had the opportunity to play an online trading game (the Two Index Game), which provides game based feedback on susceptibility to the disposition effect. 270 Saxo clients took part in a trial of these learning materials (S-M1/2).

The large majority of participants were positive about the value of the learning intervention. They found the learning materials informative (76-82%), engaging (80-82%), provided insight into their own trading (85%) and a good basis for reflective learning (76-78%).

Those who took part in the online trial of the Two Index Game felt it was fun (69%) and in combination with other learning elements, on balance, likely to help them reduce their disposition effect in real world trading (58%). In a follow-up study (S-M8) 70% agreed that they would recommend it to a fellow trader.

### *Sensor based games*

The primary role of the two sensor based-games (Auction Game and Space Investor) is as learning environments to practice and develop emotion regulation skills (with a subsidiary role in diagnosis of emotion regulation skill). In these games, game difficulty is linked to level of player arousal (as measured by heart rate); thus rewarding effective regulation of arousal whilst playing a fast-paced and arousing game. The most important user experience data on these games comes from study S-M8, since this study drew on participants from the target audience (private investors). However, user experience data was also collected on student participants in studies S-M3 and, S-M4 and fed back into game development. User experience data was also collected as part of the cycle of play testing and heuristic evaluation and reported as study S-HP below.

Feedback from investor participants on the sensor games was very positive. Nearly all (80-82%) found them engaging and fun and 95% felt xDelia games could help them learn to manage their emotions more effectively. All participants agreed that their emotions affect their financial decision-making and that better emotion management could improve their trading.

There were a few exceptions to the positive feedback. Some of the younger (student) participants in play testing found the games insufficiently challenging and engaging (even once difficulty was increased in early changes). Two elderly men (experienced day traders) were very negative about our 'video game' approach (referring to

the Space Investor and Auction Games) becoming very cross at the claim that such games could be relevant to trading. Further conversation revealed a high degree of anxiety at playing such games and a sense that their difficulty in getting to grips with the game was somewhat humiliating for them. Thus it is apparent that familiarity with and skill at video game play at both ends of the experience spectrum provides some limits on application of the approach for some audiences.

### *Diary*

Our overarching learning design gives emphasis to the problem of learning transfer from the game setting to the practice of trading. We have proposed that the use of trading diaries should play a key role in transfer, by providing the opportunity to record and reflect on emotion states and emotion regulation success and by acting as a 'commitment mechanism' for trading strategies. Data on user views of this element were primarily collected in S-M9.

The majority of participants were positive about the value of recording emotions in the xDelia Trading Diary, with 67% agreeing that keeping the diary helped them manage their emotions effectively during trading (22% undecided, 11% disagree, 0% strongly disagree). 67% felt that recording their emotional state before and after trading made them aware of their emotions (22% undecided, 11% disagree, 0% strongly disagree) and 50% felt that this awareness of their emotions during trading helped them make better trading decisions (44% unsure, 6% disagree). Part of the role of the xDelia Trading Diary is as a reflective mechanism, and 67% of participants reviewed their previous diary entries and felt that reviewing their previous diary entries provided insights into the role of their emotions in their trading decisions.

In a follow-up focus group participants confirmed the value of a diary for reflective learning but also made apparent the challenges in following the discipline to keep a diary over time. Many particularly emphasised the value of automated data capture from a trading platform significantly reducing the effort needed to keep a diary and increasing the potential to 'drill down' to look at specific episodes when reflecting on diary entries.

### *Key issues for learning design*

User feedback, both through surveys and interviews provided strong confirmation that our learning elements were engaging and promote reflective learning. Further, participants from our target audience (private investors who regularly trade on their own account) provided strong confirmation of the importance of supporting the development of emotion regulation skills.

While level of familiarity with video game does influence the acceptability of our games to participants, in their latest versions they seem well calibrated to the skills of the majority of our target audience. Further development might usefully provide for games to have configurable difficulty settings or to self-configure depending on player performance.

The diary approach clearly has potential in supporting transfer and Saxo Bank is working on incorporating features such as the automatic data capture of information about market action and trading at key points which participants indicated would be so valuable. However, implementation of such an approach must clearly be customised to the particularities of specific trading platform environments.

## EFFECTS

The following table summarise the studies that evaluated effects of the learning elements, both stand-alone and in combination. A brief discussion of the findings follows.

EVALUATION STUDIES (EFFECTS)	
S-M1	<b>Investor feedback trial A</b> <i>Perceived value of feedback on emotion regulation and disposition effect</i>
	<b>Aim:</b> In this study, participants completed an online questionnaire on their habitual emotion regulation approaches. The online system also calculated a DE score from their trading history records. They received structured personalised feedback on their emotion regulation approaches, their DE and the likely meaning of these for their trading behaviour and performance. The study evaluates whether investors see positive learning value in the experience and whether they find the experience engaging.
	<b>Findings:</b> The majority of respondents were positive about the learning value of the intervention. Most felt that the emotion regulation feedback and materials were informative, taught them something new, were interesting and engaging, and provided a good basis for reflective learning. Most felt the feedback and learning materials on the disposition effect to be informative, taught them something new, were interesting and engaging, gave them insight into their own trading, and provided a good basis for reflective learning. Two Index Game: The group who went on to complete this game were also mostly positive about the experience. They felt it was fun – very few felt it was boring – and likely, in combination with other learning elements, to help them learn to reduce their disposition effect when trading in the real world.
S-M2	<b>Investor feedback trial B</b> <i>Diagnostic and didactic value of the Two Index Game</i>
	<b>Aim:</b> This study evaluates a) whether the Two Index Game has diagnostic value, that is, does a disposition effect score in the game have predictive value in relation to propensity to display disposition effect in a real trading context and b) whether the learning intervention influences behaviour, that is, whether there are measureable differences in participants behaviour relative to non-participants before and after participation in the learning intervention.
	<b>Findings:</b> Significantly, a disposition effect score in the Two Index Game shows a significant association with a disposition effect score in real world trading. This finding is especially notable since we know from prior work that disposition effect can be highly influenced by context. Particular implications include a) strong support for the view that the disposition effect is underpinned by individual characteristics as well as trading context and b) support for the value of the TIG as a diagnostic tool and training environment for addressing the disposition effect. We also found a relationship in the Two Index Game gameplay between disposition effect and lower game profits, consistent with our expectation that when trading on the basis of some level of information a disposition effect reduces average trading performance.
S-M3	<b>Emotion regulation via the Space Investor Game (student population)</b> <i>Viability of the Space Investor Game as a training tool</i>
	<b>Aim:</b> This design study determined whether emotion regulation could be trained using the Space Investor Game with the wearable ECG sensors, and to determine which future modifications would be needed to improve the training capabilities. This study is a follow-up to IS3, but with a more robust sensors package.
	<b>Findings:</b> The study has shown that the game is an effective space where participants in the learning intervention have the ability to monitor their progress or practice their newly learned emotion regulation skills. The study also led to

	<p>several recommendations for future improvements, such as combining the biofeedback signals with explicit tips and hints on strategies that participants can use during the game levels. The main findings from this study were that a) the Space Investor Game induces arousal in several game levels, b) arousal management helps players to perform better in the game, and c) the game requires further tweaks to strengthen the game, such as using a continuous rather than a discrete arousal input.</p>
S-M4	<p><b>Emotion regulation via the Auction Game (student population)</b>  <i>Viability of the Auction Game as a training tool and the effect of ER strategies on performance</i></p> <p><b>Aim:</b> This study was conducted in two parts. The first part of the study calibrated the Auction Game (didactic mode) and the influence of biofeedback on emotion regulation and decision performance. The second part of the study examined the training effect of biofeedback and arousal-influence on emotion regulation and decision performance. Specifically, we considered three questions: a) Does the Auction Game in didactic mode provide an effective space for practicing emotion regulation? b) How do different ER strategies, as measured by physiology and ER questionnaires, affect game performance? (3) Do players improve their skills in emotion regulation, as measured by physiology and ER questionnaires, in different modes in the game?</p> <p><b>Findings:</b> We found that the two main requirements for an emotion regulation learning environment are met: the game induces high levels of physiological arousal and heightened arousal in turn significantly worsens an individual's decision performance. Hence, the Auction Game in didactic mode rewards active down-regulation of high levels of arousal and provides an environment in which emotion regulation can be practiced and rewarded. Subjects who used either the emotion regulation strategies 'emotion reappraisal' or 'emotion suppression' performed better in the game than those subjects who did not apply any of these strategies. Hence, the game rewards the use of these emotion regulation strategies. Furthermore, we found a positive correlation between subjects' LF/HF-ratio and their variance of arousal values during the game. We interpret this finding as an indication that subjects with a low LF/HF-ratio are more flexible to constantly keep their arousal down, and hence expose a lower variance on the arousal signal. We did not find a significant correlation between decision performance and heart rate variability however. Subjects picked up the game concept and pursued high effort in order to regulate their arousal level. In fact, even though most of the subjects are initially unfamiliar with the concept of emotion regulation, they actively tried to manage to down-regulate high levels of arousal.</p>
S-M5	<p><b>Learning via the Auction Game (student population)</b>  <i>Viability of the auction game in training phasic response and implications for the disposition effect</i></p> <p><b>Aim:</b> This study evaluated the Auction Game in diagnostic mode as a learning tool in relation to emotional overweighting of losses. The questions we addressed were a) can people learn to control their emotional phasic responses? and b) does this group perform better in a subsequent task relating to the disposition effect, as measured by the Two Index Game, compared to a control group? The first part of the study calibrated the Auction Game in diagnostic mode and the Two Index Game. The second part of the study examined the effect of a learning intervention (the Auction Game in didactic mode and the Space Investor Game) on phasic emotional responses in the Auction Game (diagnostic mode) and on the disposition effect, as measured by the Two Index Game.</p> <p><b>Findings:</b> The results provide evidence that a single one shot intervention is not fruitful in improving subjects' skills on effective emotion regulation. However, the results provide an indication that subjects' emotional constitution, even between unrelated tasks, is a driver of the DE and that the auction game in diagnostic mode elicits emotions that are relevant for decision making. With the results provided so far we only mapped the physiological responses to gains and losses to the DE. Mapping physiological responses to regret on exposedness in the TIG were not successful. The increase in disposition effect following an emotion regulation training intervention is puzzling but may be a short term effect due to exhaustion of regulative capacities. We speculate that whilst the long term learning effect of the game may be to improve self-regulation capabilities, the short term effect may be to temporarily exhaust self-monitoring capacity increasing reliance on system 1 emotion mediated decision paths.</p>

S-M6	<b>Learning and transfer with multiple interventions I (student population)</b> <i>Are the games in didactic mode effective and do they enable transfer as measured by economic performance</i>
	<b>Aim:</b> This 3-week longitudinal study, which was designed and conducted in parallel to SM-7, established which games and in what combinations are most effective in terms of training emotion regulation skills and enabling transfer. Outcomes were measured via the Two Index Game (for the disposition effect), the Auction Game in diagnostic mode, and the Weber task (an additional measure for the disposition effect).
	<b>Findings:</b> The learning interventions tested here are successful in increasing subjects' level of emotion regulation as measured by the emotion regulation questionnaire and by the psychophysiological heart rate variability. However, the differences between the treatment conditions are small, making it hard to judge the incremental contribution of the different interventions. In this study the impact of ER training on tasks of economic decision-making (TIG, AUC-DIAG, and the Weber task) appear to be weak.
S-M7	<b>Learning and transfer with multiple interventions II (student population)</b> <i>Is the SIG and mindfulness effective and do they enable transfer as measured by economic performance</i>
	<b>Aim:</b> In previous studies (MF1, MF2), we established that short single-shot exercises on emotion regulation such as short meditation affect decision-making processes in students. However, the question remained whether these effects could be strengthened by practising these exercises over a longer period of time or in repeated sessions. In the present study, we aimed at investigating whether repetition of the same exercise over a limited period of time promoted learning effects of emotion regulation skills. The goal was to examine the learning effects of emotion regulation strategies (Space Investor Game, mindfulness exercise, or a combination of both) over a three weeks period. The second aim was to determine whether these skills transferred into a financial decision context and as measured by the disposition effect using the TIG and the Weber stock market task.
	<b>Findings:</b> The students showed changes in trait and state emotion regulation and in state (but not trait) mindfulness over the different emotion regulation training sessions compared to the control group. Body vigilance increased in all treatment groups compared to the control group as result of the emotion regulation training sessions, and the use of maladaptive emotion regulation strategies (suppression) declined across all participants. This indicates that the emotion regulation exercises were effective. Although both the Space Investor Game and mindfulness were associated with emotion regulation, the effects of each group separately was for the most part equal or at least not much weaker than the combined mindfulness x Space Investor group. This suggests that combining the two trainings is not a necessary prerequisite for a training programme which aims at increasing emotion regulation skills. The present data showed that although the treatment conditions were effective in increasing state mindfulness and emotion regulation skills, no effects were observed on the disposition effect in the Weber task. In contrast, a gradual increase in the disposition effect was noted for all participants on the TIG.
S-M8	<b>Investor trials of learning interventions</b> <i>Can emotion regulation training reduce investors' susceptibility to the disposition effect</i>
	<b>Aim:</b> This longitudinal study investigated whether emotion regulation training via mindfulness training, Auction Game and Space Investor Game can reduce private investors' and traders' susceptibility to the disposition effect. Specifically, the questions were: a) Do the sensor games produce improvements in interoception? b) Does the combination of sensor games and mindfulness training produce a reduction in disposition effect? And c) does the target audience find these training interventions engaging and a useful basis for reflective learning?

	<p><b>Findings:</b> This study adds to evidence that the target audience find the xDelia learning games and mindfulness training engaging and likely to promote useful learning relevant to their trading behaviour. The results on interoception suggest that not only do the games improve emotion regulation as found in previous studies but offer direct evidence that they may do so via improved attention to internal physiological states (interoception). The interoception tool developed as part of xAffect functionality and tested in this study may thus provide an important contribution to feedback and learning about emotion regulation. The study provides further evidence that the TIG disposition effect measure has test retest validity given the moderately good agreement in disposition effect scores across multiple plays. While drop out among participants limited significance of findings, we also find the mindfulness training to improve both mindfulness and emotion regulation. Evidence on disposition effects is weak and mixed. However, there is some indication that disposition effect rises immediately with engagement in sensor based games and falls subsequently over a period of mindfulness training, in contrast to a steady rise for those not engaged in mindfulness training.</p>
S-M9	<p><b>Reflective diary (investor population)</b>  <i>Investor experience with a reflective diary</i></p>
	<p><b>Aim:</b> This study trialled a paper version of the reflective diary with a cohort of investors collecting their feedback for use as input to the design of the final version of the diary tool.</p>
	<p><b>Findings:</b> The consensus was that a trading diary was important, both for keeping a record of trades in order to track money made and lost, but also for recording a form of snapshot of the state of the market at the time of the trade. The interviews and survey responses confirmed that our diary-based approach to supporting reflection and emotional awareness during trading was seen as valid by our target stakeholders, and that the support for recording emotions provided in the pilot xDelia diary promoted emotion awareness which participants felt would lead to better trading decisions. An overwhelming majority were in favour (almost 100%) of our approach and were very positive about the idea of integrating sensor based physiological feedback into the diary. An important issue that was emphasised by several participants was the value of automated capture of trading information and the facility for rapid capture of emotion state.</p>

### Diagnostic validity

Three main elements of the xDelia Learning Pathway are intended to have a role in diagnosis and feedback. The Two Index Game provides a game based measure of disposition effect, the Online Diagnostic Questionnaire provides diagnosis of habitual emotion regulation strategies and the two sensor based games (the Space Investor and the Auction Game) can be used to provide feedback and train emotion regulation capability.

#### Two Index Game

The Two Index Game was designed primarily as a game space in which traders could learn about a particular bias (the disposition effect) and practice emotion regulation skills without risk to real world trading performance. However, we also felt that for traders with little existing trading record it might, also offer the possibility of diagnosing a propensity to a disposition effect. Early work in Year 2 had already shown the incidence of disposition effect in gameplay presenting a similar distribution to disposition effects typically detected in market data.

In Year 3, feedback trials (S-M1, S-M2) offered the chance to examine the correlation between disposition effect in gameplay and in actual trading. We found a significant positive correlation between disposition effect scores calculated from participants' real trading history and gameplay ( $r = 0.28$ ;  $p < .05$ ;  $N = 58$ ). Further this correlation with game based disposition effect remained consistent across three separate periods of trading history.

While the correlation is modest, there are good reasons why we should not expect a very high correlation. First, we know that disposition effect is affected by context. While the game context was standardised across participants, participants were, in their real world trading, trading a wide range of different assets and facing dissimilar and changing market conditions. Secondly, separate findings (see S-M8) suggest that it may take several plays of the Two Index Game before participants' master game mechanics sufficiently to really focus on the trading task. In the feedback trial participants only played the game once. That we find a relationship between a game based measure (where the only incentive is a desire to get a high score) and a real world trading context with significant sums of money at stake is highly notable. We also find the Two Index Game measure of disposition effect to have reasonable test re-test reliability (S-M6, S-M7, S-M8 – e.g. S-M8 intraclass correlation coefficient = 0.74,  $p < .000$ ).

These results not only provide validation of the game as a diagnostic measure but also are an important contribution to our understanding of the disposition effect suggesting such biases to have a trait component as well as being influenced by context.

### Sensor based games

Year 3 studies also provided support for the diagnostic validity of the sensor based games. S-M4 also shows a significant correlation between participants self-ratings of habitual emotion regulation strategies and game performance, although the data also suggest that the game rewards reappraisal and suppression strategies equally (we hypothesised reappraisal to be more effective).

S-M5 also shows emotion regulation as measured by balance in physiological responses (i.e. heart rate) to gains and losses to predict game performance.

### Online Diagnostic Questionnaire

While the questionnaire scales used in the diagnostic survey are well tested and well understood and the use of this questionnaire was part of an apparently successful learning intervention (as measured by change in disposition effect), the results on relationship between questionnaire measures and trading behaviour were disappointing. In S-M1/2 there was no significant correlation between questionnaire measures and disposition effect. Although measures of emotion regulation (in the ERQ) did show a significant correlation with holding times for both assets in gain and assets in loss. S-M6 also showed mixed results. Other studies (TIG-1, S-M8) did show a relationship between effective emotion regulation and disposition effect as measured in the TIG. On balance, the best we can say is that these results on the questionnaire are inconclusive.

We consider there to be two plausible explanations of this result. A) It is possible that investors were more likely to answer positively to questions about emotion regulation if they experience a significant need to regulate emotions during their trading. In other words the ERQ may be picking up both approach to emotion regulation and amount of regulation. B) Reappraisal may be associated with different goals. If the goal is to manage emotional reactions in the interest of a balanced approach to decision-making then we would expect a reduction in disposition effect. However if the goal is to avoid negative emotions by avoiding responsibility for outcomes then it could lead to greater disposition effect. It is also possible that emotion regulation has no relationship to disposition effect. However, given results in other studies which do find a relationship (including a study conducted in parallel to xDelia at the Open University Business School) it seems likely that there are contingencies which our trial has not accounted for.



These results suggest that the online diagnostic questionnaire should be developed further to improve validity in relation to trader behaviours. First, we suggest recasting the ERQ questions to focus on habitual approaches to emotion regulation in everyday life. Second, we suggest developing a dedicated scale which measures traders own perceptions of susceptibility to emotion effects on their trading. (This work is now ongoing).

### *Emotion regulation, mindfulness and interoception*

#### **Sensor based games**

A first and basic concern in evaluating our learning games was to establish whether they behave as designed and provide a valid learning environment.

Studies S-M3 and S-M4 addressed this question for the Space Investor and Auction Games respectively. In both games better emotion regulators got higher scores, participants self-reports of arousal correlated with game based measures of arousal, and participants reported that paying attention to their arousal levels helped them play the games better. Game performance also, as intended, is higher for those who showed greater success in controlling their levels of physiological arousal. Study S-M4 also showed emotion regulation (as measured by high frequency heart rate variability) to predict management of arousal levels and hence performance in the game.

Study S-M3, did though reveal uneven levels of difficulty across game levels rather than a steady increase in difficulty as intended. The study also raised issues about the use of discrete bands of arousal levels rather than a continuous arousal measure in the Space Investor game. This led to revisions to the game design and a slight change in Space Investor in level difficulty and operationalisation of arousal values to feed into the game for the SI-version that was eventually used in studies S-M6 and S-M7.

A second question was whether these games would be successful in supporting the improvement of emotion regulation skills. Evidence on this question comes from studies S-M6 and S-M7 (with students) and S-M8 (with private investors).

S-M6 finds that effectiveness of emotion regulation as measured both by questionnaire and heart-rate variability as measured in the auction game does improve over a three week training course using sensor based games.

S-M7 was similar to S-M6 but used the Space Investor game instead. Moreover, in this study, a mindfulness exercise was introduced into the course. As hypothesized, playing the Space Investor repeatedly over a three-week period was associated with increases in self-reported interoception behaviours (i.e., attention to bodily cues). Although trait levels of emotion regulation remained unaffected by Space Investor or mindfulness, state emotion regulation (RA) did demonstrate increased levels compared to controls for people who played SI. Only the mindfulness group showed a significant and consistent decline throughout the three trials. As mindfulness is well-associated with improvements in emotion regulation, this likely reflects a shift of attention by participants from RA-strategies to increasing levels of interoception (i.e., via the mindfulness exercise that involved a strong focus on bodily cues). The finding that body vigilance (i.e., attention to bodily signals) improved consistently in all conditions compared to controls, supports the view that the current approaches were effective in improving interoception, which is an important prerequisite for emotion regulation.

S-M8 provided further evidence for the impact of the sensor games, showing gameplay to be associated with improvements in interoception (although these improvements seemed independent of the use of biofeedback in the games).

Our Year 3 studies also sought to integrate evaluation of the role of mindfulness training. S-M7 shows our training interventions to improve state mindfulness and interoception (in a student population) and S-M8 provides support for the validity of the training approach with a private investor population.

### *Financial behaviour*

Finally, we also sought to evaluate whether our training approaches bring about change in financial behaviour. In most cases we used the Two Index Game as our measure of financial behaviour (access to individuals' real trading data is very difficult and such data does not exist for student participants). However, in one study (S-M1/2) we did have the opportunity to take a before and after measure in relation to real trading behaviour.

In our feedback trial study (S-M1/2), which involved diagnosis and feedback on habitual emotion regulation strategies, and on disposition effect with accompanying learning materials we measured disposition effect in actual trading data for each participant at three time periods; before the training and in two periods after. We found no significant difference between the training group and a comparison group prior to the training but significantly lower disposition effect in the training group (and relative to the comparison group) following the training. This represents fairly strong evidence for the impact of our training approach on the disposition effect. Given the failure of prior 'debiasing' research to show such effects, especially outside the laboratory (Bazerman, 2002; Fischhoff, 1982; Lilienfeld, Ammirati, & Landfield, 2009), this is an important vindication of our approach.

Intriguingly and perhaps importantly for banks who deploy our approaches, there is evidence that clients who participated in our training intervention may have persisted as actively trading bank clients for longer than a comparison group.

Results on the impact of training on the disposition effect as measured in the Two Index Game are less positive. While S-M8 provides some evidence for a post training fall in disposition effect, both S-M5 and S-M7 show increases in disposition effect after training (and S-M8 shows an initial rise in DE).

One explanation is that self-regulation capability is like a muscle and can become exhausted (Muraven & Baumeister, 2000). Since both the sensor games and the Two Index Game require active self-regulation, it is possible that the short term effect of playing the sensor games (which require active self-regulation) is to exhaust self-regulation capacity, whilst learning effects take time to build. Participants playing the Two Index Game immediately after the sensor games then have depleted self-regulatory capabilities leaving them more prone to emotion driven biases.

We do though see an increase in disposition effect across multiple plays of the Two Index Game in several studies. One possible explanation is suggested by comments made by several participants in follow-up interviews. A typical comment was "I wasn't really being myself as a trader until I had played it a few times". Further questioning suggested that in initial plays they were quite focussed on gameplay mechanics. It was only having mastered these that they felt free to focus on making as much money as possible. Disposition effect is understood to be founded in emotional reactions to gains and losses; and thus most likely to occur when the

player is focused on levels of gain and loss rather than on game mechanics. Thus, it may be that the diagnostic value of the game is strongest after sufficient play to learn the game mechanics.

#### **KEY IMPLICATIONS FOR LEARNING DESIGN AND FURTHER RESEARCH**

Taken together, our Year 3 studies provide much support for the validity of the learning approach and the learning elements which make it up.

- We have very positive user feedback suggesting our learning approach to be engaging, enjoyable and a good basis for learning.
- There is good evidence for the effects of the learning interventions in achieving proximal goals of improving emotion regulation, mindfulness and interoception.
- Our studies support the value of our sensor based games in diagnosing emotion regulation capabilities and the value of the Two Index Game in diagnosing a propensity to a disposition effect.
- We show a significant impact of the initial stage of our learning pathway on disposition effect as measured in real world trading behaviour.

However, as is normal with such research we are also left with some puzzles which merit further research and in some cases suggest a need for further development of elements of our learning pathway.

- In some cases learning interventions lead to a paradoxical increase in disposition effect as measured by the Two Index Game. We have advanced some explanations for this finding but further research is needed to establish whether these are correct. This may involve gaining a better understanding of the ways in which playing behaviour evolves over time in repeated plays of the Two Index Game.
- Whilst we hypothesised the use of a reappraisal strategy to be associated with better performance in our emotion regulation games, in some cases better performance is also associated with use of a suppression strategy for emotion regulation. This is unexpected in the light of previous research on these emotion regulation strategies and merits further investigation.
- The diagnostic questionnaire scales have mixed success in predicting financial behaviour and further development is needed here.

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